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THE HYDRAULIC FILL DAMS OF THE MIAMI CONSERVANCY DISTRICT.

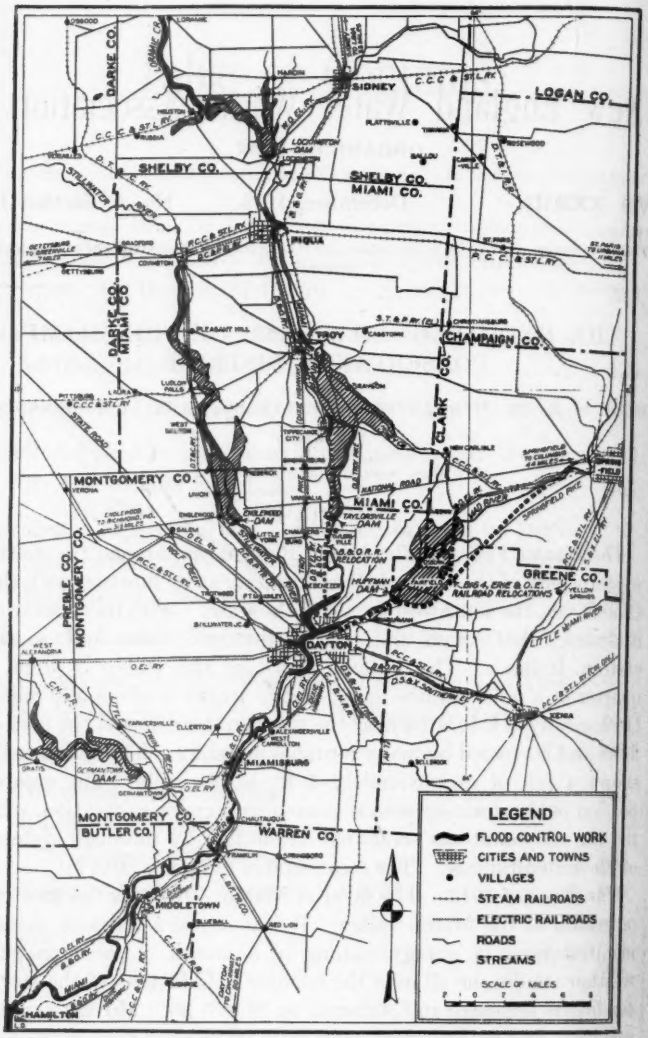
BY H. S. R. MC CURDY, DIVISION ENGINEER, MIAMI CONSERVANCY DISTRICT.

[*Read September Convention, 1919.*]

PRELIMINARY.

The Miami Valley. The Miami River flows through the southwestern part of the state of Ohio, forming, at its junction with the Ohio River, the southwest corner of the state. With its tributaries it drains 5 430 square miles in southwestern Ohio and southeastern Indiana. The general width of the valley is from a quarter of a mile to three miles, and its length is about 120 miles. Geologically it is located near the southern terminus of the glacier flows and is crossed by many terminal moraines. The river profile shows a fall of approximately 4 ft. to the mile. The greater portion of the drainage area is cleared land under cultivation, with the run-off conditions somewhat intensified by thorough systems of tile underdrainage. The mean annual rainfall is 36½ in.

The Flood of 1913. The flood of March, 1913, was the greatest on record in the Miami valley. It was one of a series of violent manifestations of energy coming in a month of most unusual weather conditions all over the country. Evidences of the storm conditions appeared in California on March 20. Moving rapidly eastward, and gathering intensity as it traveled, it gave expression to its force in the shape of destructive tornadoes in Omaha, Neb.,


DARKE CO.
SIDNEY
LOGAN CO.
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MIAMI CO.
PIQUA
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TROY
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CLARK CO.
MONTGOMERY CO.
MIAMI CO.
GREENE CO.
PREBLE CO.
MONTGOMERY CO.
DAYTON
MIAMISBURG
MONTGOMERY CO.
BUTLER CO.
WARREN CO.
MIDDLETOWN
HAMILTON
LEGEND
FLOOD CONTROL WORK
CITIES AND TOWNS
VILLAGES
STEAM RAILROADS
ELECTRIC RAILROADS
ROADS
STREAMS
SCALE OF MILES

FIG. 1.

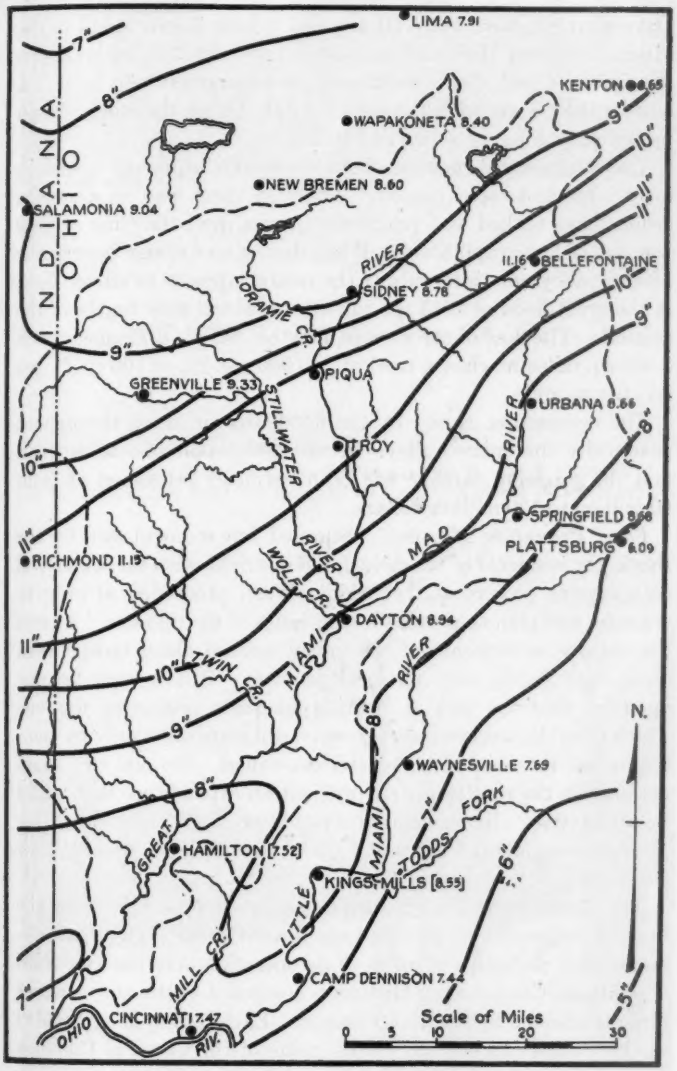


FIG. 2. RAINFALL, MARCH 23–27, 1913.

Davenport, Ia., and Terre Haute, Ind. Rain began to fall in the Miami valley on March 23 and lasted until the 27th, although on the first and last days the rainfall was comparatively light. A map of the region, with the total rainfall during the storm shown by isohyetal lines, is shown in Fig. 2.

The conditions at the time of the storm were especially favorable for a large and rapid run-off. Although there was no snow the ground was soaked and practically frozen, and the time of year was one of low evaporation. While during an average year in the Miami valley one third only of the rainfall appears as stream flow, in the great flood of 1913 the run-off was about nine tenths of the rainfall. The flow of the river at Dayton, with a drainage area of 2 500 sq. miles reached a crest of 250 000 sec. ft., or 100 cu. ft. per sec. per sq. mile.

The destruction caused by the flood was appalling throughout practically the entire valley. About 400 people lost their lives, and the property damage has been variously estimated at from 60 million to 150 million dollars.

Flood Prevention Measures. Stunned but momentarily by the shock, the residents of the devastated districts, with the wonderful recuperative powers of the Middle West, proceeded at once to organize and plan to prevent a recurrence of the disaster. At first the various settlements of the valley worked along independent lines, each seeing only its local problem. But it soon became apparent that the task of securing adequate protection was one which could be worked out to a successful conclusion only by combining the interests of all parties concerned. No one city could accomplish the result for itself without an expenditure that would be prohibitive. Recognizing this condition, the Conservancy Law of Ohio was passed February 6, 1914, about eleven months after the flood.

The Conservancy Law is such a distinct step forward along the lines of coöperative effort looking toward great public improvements that perhaps a word as to its operation may not be remiss. The Miami Conservancy District is composed of the nine counties directly affected by the improvement. Each county is represented in the Conservancy Court by its judge of the Court of Common Pleas. Sitting as a body this court, on June 28, 1915, voted to

FIG. 3. THE FLOOD WATERS ENTERING THE BUSINESS DISTRICT.
At the crest of the flood the water stood level with globes on street lamps.

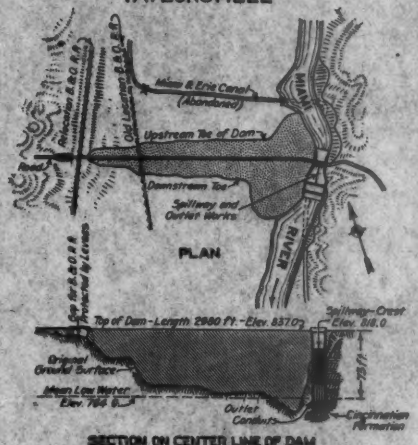
FIG. 4. THE FLOOD IN THE RESIDENTIAL DISTRICT.

create the district, and appointed three directors with executive powers to proceed with a program of flood protection for the valley. The court also appointed three appraisers to evaluate the damage and benefits resulting from the improvement. Fig. 6 illustrates the operation of the law, and follows in more or less detail the various steps necessary before construction can be started.

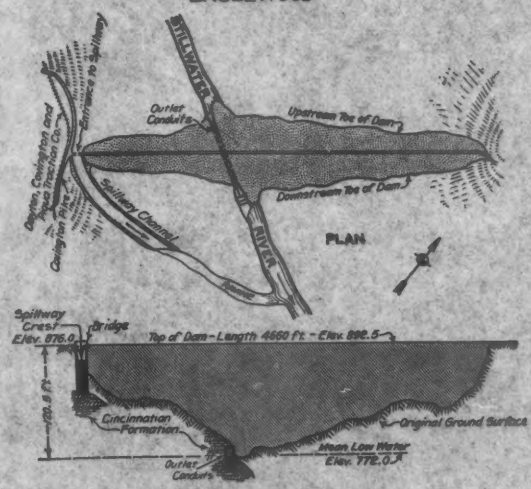
FIG. 5. AFTER THE FLOOD.

The Official Plan. A thorough investigation of practically every conceivable scheme of flood protection was made. The final result showed that the real solution lay in limited channel improvement and levees through the cities, supplemented by a system of retarding basins, the function of the retarding basins being to hold back temporarily the flood flows and allow them to escape into the river channels below at such a rate only as the improved channels can accommodate. A delicate adjustment of the relative capacities of the component parts of the system was necessary, and the balance between what could be done along the line of

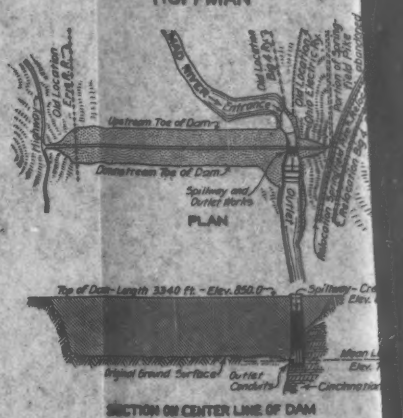
TAYLORSVILLE

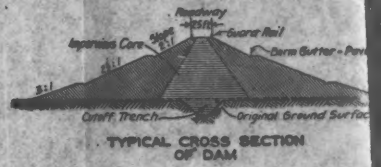


ENGLEWOOD

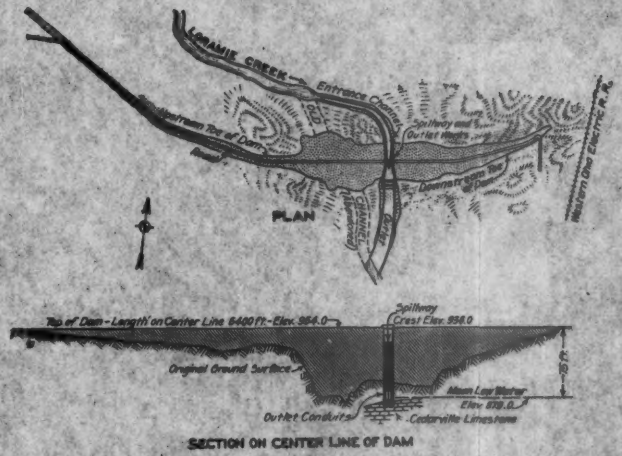


HUFFMAN

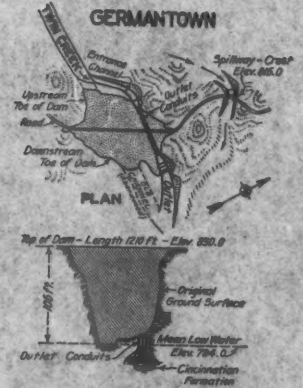

Upstream Toe of Dam
Downstream Toe of Dam
Spillway and Outlet Works
PLAN
Top of Dam - Length 3340 ft. - Elev. 850.0
Original Ground Surface
Outlet Conduits
SECTION ON CENTER LINE OF DAM



LOCKINGTON



GERMANTOWN



State of Ohio
The Miami Conservancy District

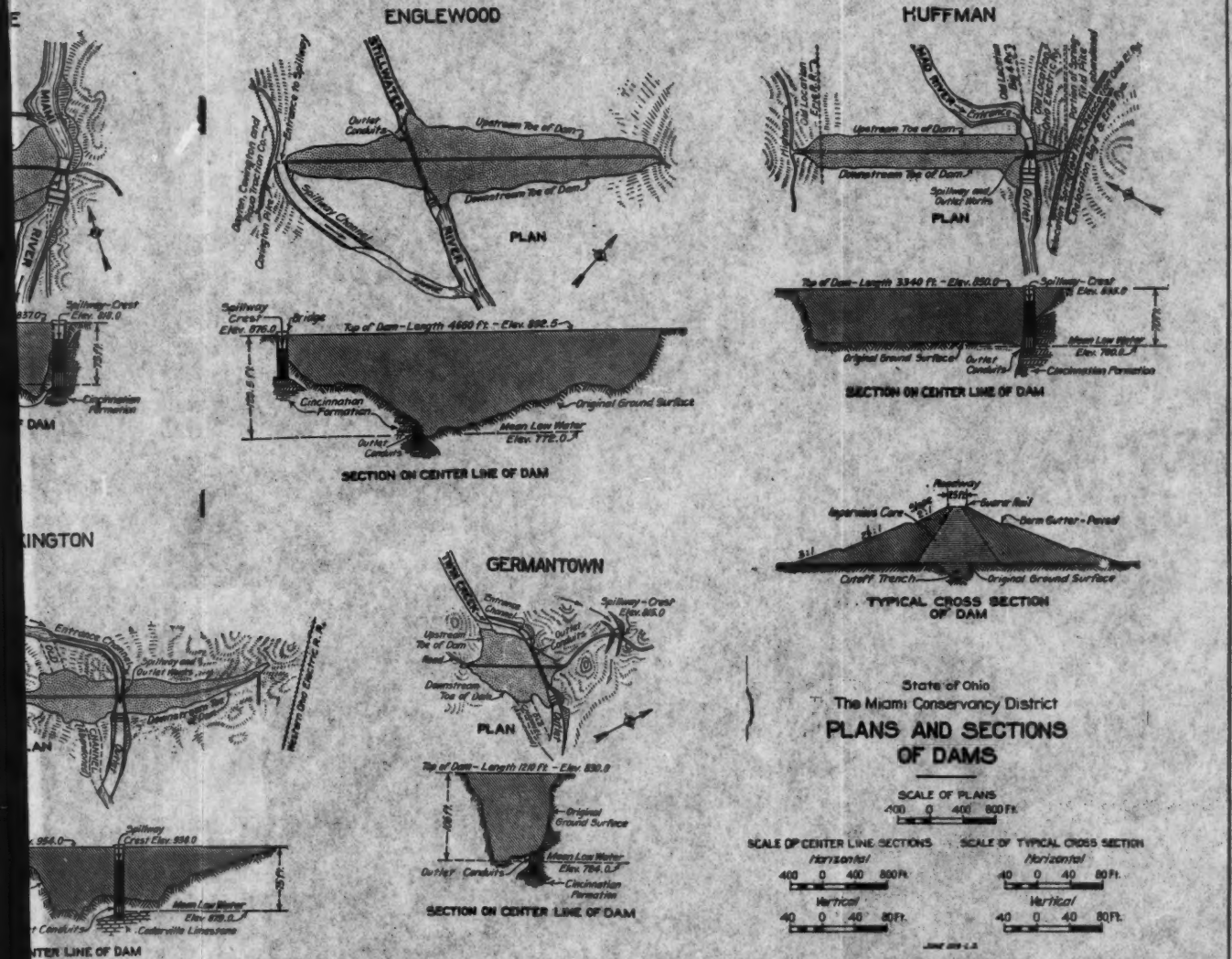
PLANS AND SECTIONS OF DAMS

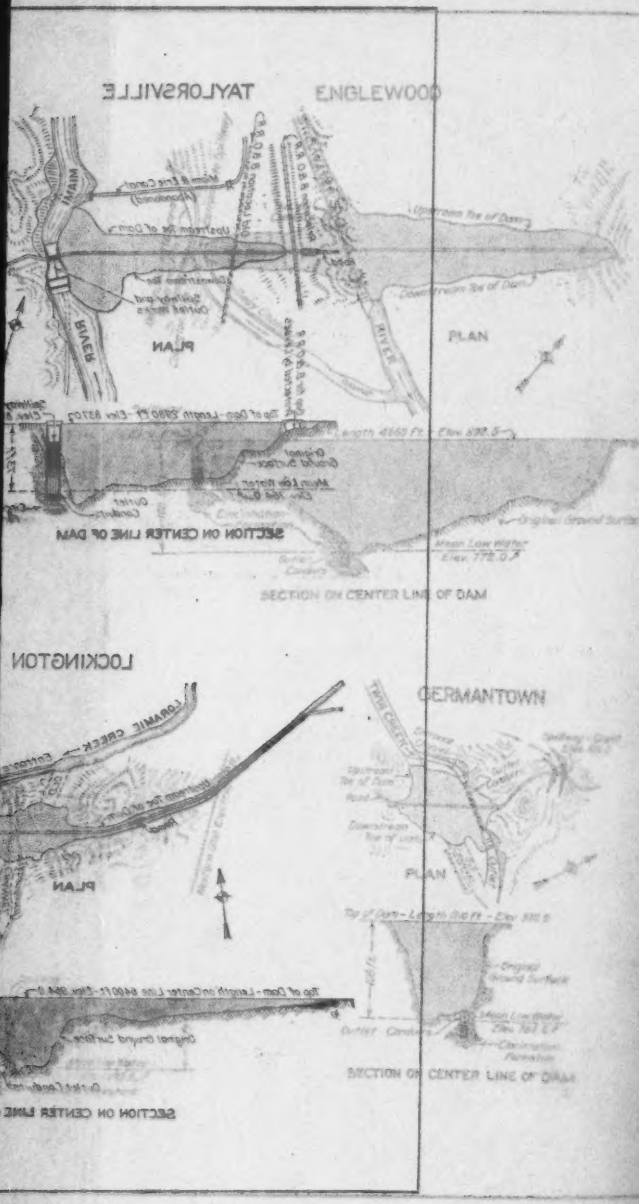
SCALE OF PLANS
400 0 400 800 Ft.

SCALE OF CENTER LINE SECTIONS
Horizontal
400 0 400 800 Ft.
Vertical
40 0 40 80 Ft.

SCALE OF TYPICAL CROSS SE
Horizontal
40 0 40 80
Vertical
40 0 40 80

PLATE I.
N. E. W. W. ASSOCIATION.
VOL. XXXIII.
MCCURDY ON
HYDRAULIC FILL DAMS.




ENGLEWOOD
PLAN
SECTION ON CENTER LINE OF DAM
GERMANTOWN
PLAN
SECTION ON CENTER LINE OF DAM

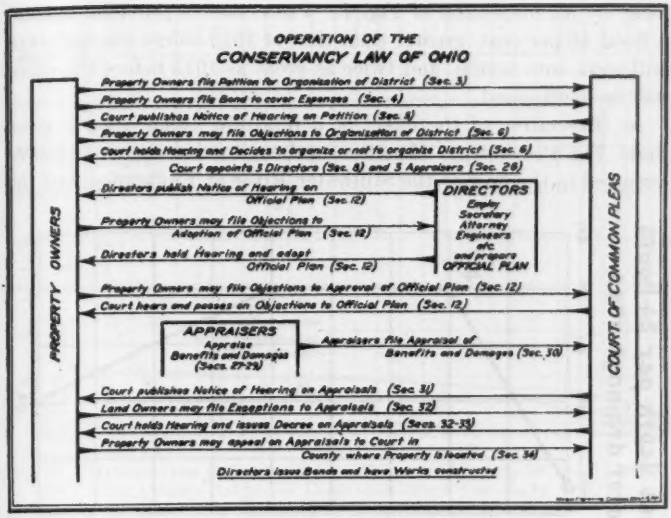

OPERATION OF THE
CONSERVANCY LAW OF OHIO
PROPERTY OWNERS
COURT OF COMMON PLEAS
Property Owners file Petition for Organization of District (Sec. 3)
Property Owners file Bond to cover Expenses (Sec. 4)
Court publishes Notice of Hearing on Petition (Sec. 5)
Property Owners may file Objections to Organization of District (Sec. 6)
Court holds Hearing and Decides to organize or not to organize District (Sec. 6)
Court appoints 3 Directors (Sec. 8) and 3 Appraisers (Sec. 26)
Directors publish Notice of Hearing on Official Plan (Sec. 12)
DIRECTORS Employ Secretary Attorney Engineers etc. and prepare OFFICIAL PLAN
Property Owners may file Objections to Adoption of Official Plan (Sec. 12)
Directors hold Hearing and adopt Official Plan (Sec. 12)
Property Owners may file Objections to Approval of Official Plan (Sec. 12)
Court hears and passes on Objections to Official Plan (Sec. 12)
APPRAISERS Appraise Benefits and Damages (Secs. 27-29)
Appraisers file Appraisal of Benefits and Damages (Sec. 30)
Court publishes Notice of Hearing on Appraisals (Sec. 31)
Land Owners may file Exceptions to Appraisals (Sec. 32)
Court holds Hearing and issues Decree on Appraisals (Secs. 32-33)
Property Owners may appeal on Appraisals to Court in County where Property is located (Sec. 34)
Directors issue Bonds and have Works constructed

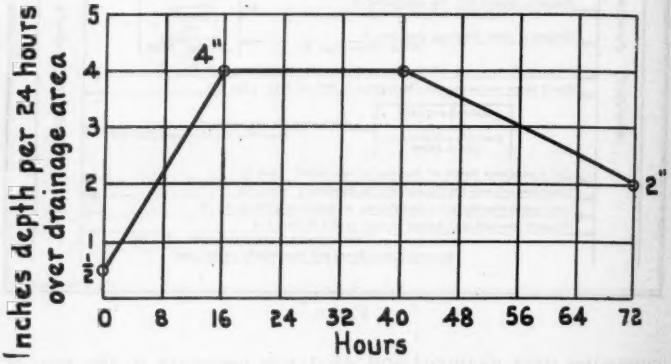
FIG. 6.

improving river channels and what was necessary in the way of reservoir storage was the subject of thorough and prolonged study. The final decision called for five retarding basins, the locations of which are shown on the general map of the district, Fig. 1. The principal dimensions of the dams, together with correlative data, are shown in Table 1, while plans and sections appear in Plate I.

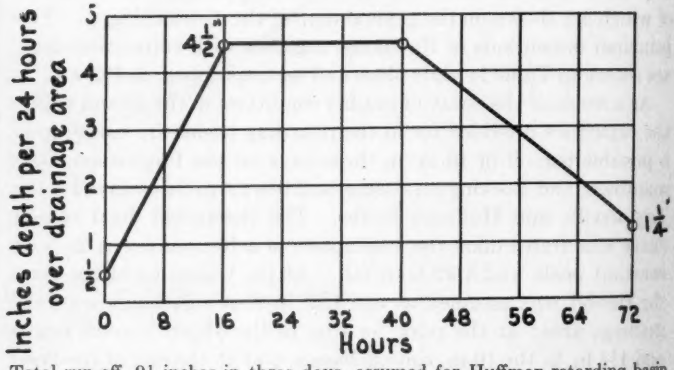
As a result of the study of rainfall conditions in the Miami valley the capacities provided for in the retarding basins are based upon a possible run-off of 10 in. in three days for the Englewood, Germantown, and Lockington basins, and 9½ in. in three days for the Taylorsville and Huffman basins. The theoretical flood run-off curve was drawn upon the assumption of a 16-hour rise, a 24-hour constant peak, and a 32-hour fall. At the beginning of the flood the run-off was assumed as one half inch per 24 hours over the drainage area; at the peak, as 4 in. in the 9½-in. run-off basins and 4½ in. in the 10-in. run-off basins, and at the end of the flood as 2 in. in 24 hours over the drainage area for the 9½-in. basins and 1¼ in. for the 10-in. basins. The foregoing will be

clear by an inspection of Fig. 7. Protection is provided against a flood 40 per cent. greater than that of 1913 before the spillways will come into action, and twice as great as 1913 before the dams will be overtopped.

As illustrative of the effect of a retarding basin upon a great flood, Fig. 8 is shown. Here is seen the reduction that would have occurred in the flow of the Stillwater River at Englewood had the



Total run-off, 10 inches in three days, assumed for Germantown, Englewood, and Lockington retarding basins.



Total run-off, 9½ inches in three days, assumed for Huffman retarding basin and for drainage area above Taylorsville but below Lockington.

FIG. 7. THE MIAMI CONSERVANCY DISTRICT ASSUMED RUN-OFF DIAGRAM.

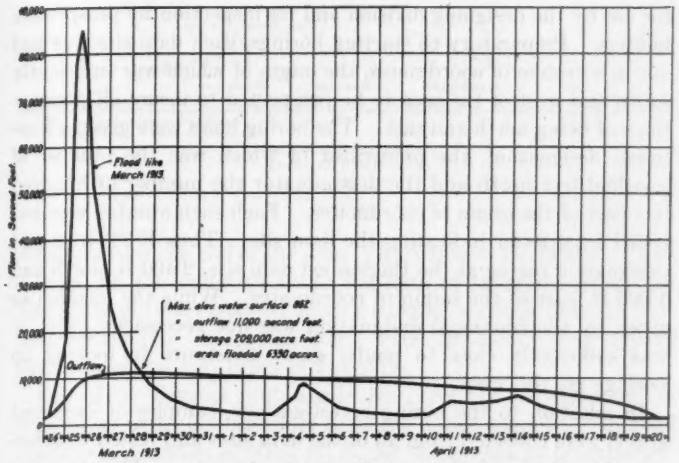


FIG. 8. HYDROGRAPHS SHOWING SIZE OF FLOOD OF MARCH, 1913, AT ENGLEWOOD RETARDING BASIN, AS COMPARED WITH THE RATE OF OUTFLOW FROM THE BASIN IF IT HAD BEEN IN EXISTENCE.

dam been in service during the great flood of 1913. The combined effect of the four retarding basins above Dayton is figured to reduce the flow through that city, should a flood equal to that of 1913 occur, from 250 000 sec. ft. to 110 000 sec. ft. Similarly, the effect of the five basins above Hamilton would be to reduce the flow from 354 000 sec. ft. to 200 000 sec. ft.

As soon as the general scheme for flood prevention was formulated, subsurface investigations were begun, looking to the development of underground conditions at all of the proposed dam sites and elsewhere in the district where large construction was contemplated. In conjunction with a recognized authority upon the subject, the local geology was studied. Borings, both in earth and rock, were put down in sufficient number to reveal the foundation conditions for dams and appurtenant structures. Ledge rock was located upon which to build the spillways and conduits, and this rock was thoroughly investigated. Borrow pits, both for embankment materials and for concrete aggregates, were developed and exhaustive tests made of their products. Earth samples, taken by the dry method, and rock cores were preserved in cabinets

for use by the designing division and for inspection by prospective bidders. Preparatory to starting borings, each dam site was laid out in a system of coördinates, the origin of which was sufficiently south and west of the area to be prospected to insure all designations of being north and east. The boring holes were given a fractional designation, the numerator of which was the number of hundred feet north and the denominator the number of hundred feet east of the origin of coördinates. Each such number was preceded by a letter indicating the dam site. Thus E 24/40 would designate a boring at the Englewood dam site, 2 400 ft. north and 4 000 ft. east of the origin of coördinates. While the location as given by the fractional designation was not necessarily exact, it was sufficiently close to render great assistance in looking up borings on the map.

In addition to the boring investigations, samples of sand and gravel were collected from all of the dam sites and tested to determine their value for use as concrete aggregates. Also, the proposed borrow pits were sampled and mechanical analyses made of the material to be used for the hydraulic fill. Material passing the 200-mesh sieve was subjected to such tests as would determine its suitability for use as the core of a hydraulic fill dam. Particularly were such "fines" compared as to rate of settling, etc., with core material from hydraulic fill dams in other parts of the country.

The natural conditions at all of the five dam sites dictated the adoption of the earth type. Ledge rock occurs at one side of the valley only, in each case, while deposits of glacial débris, admirably suited for hydraulic sluicing, are found in abundance at favorable locations. The cross-section adopted for all of the dams is shown in Fig. 9, the width of core material in the center being arbitrarily assumed at any particular elevation as equal to the distance down from the top of the dam. Where the foundation material was porous a 4-ft. blanket of impervious material was placed to increase the ratio of length of travel of seepage to head of water.

Each dam is provided with a concrete spillway, about 15 ft. down from the crest, and with outlet works. At Englewood and at Germantown the openings are in the form of covered conduits through the dam at the old river channel, with a separate spillway

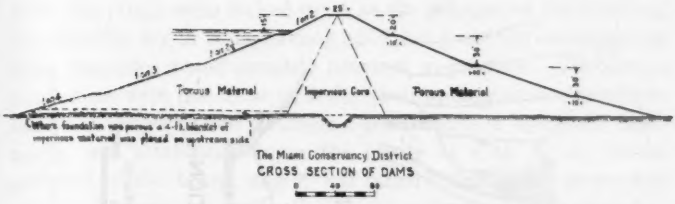


FIG. 9.

structure near the end of the dam. At Taylorsville, Huffman, and Lockington the spillways are in the form of an ogee weir located also at the old river channel, having suitable openings near the base to accommodate the stream flow. Figs. 10 and 11 show typical examples of the two types of structure.

One of the distinct problems in the design of the dams was in connection with the issuing jet from the outlet conduits. In flood conditions velocities of 50 or 60 ft. per second are to be expected. To allow any such onrush of water to project itself into an unprotected river channel would be to invite disaster and endanger the dam itself. A search for literature upon the subject brought forth little that was directly applicable. While the principles of the

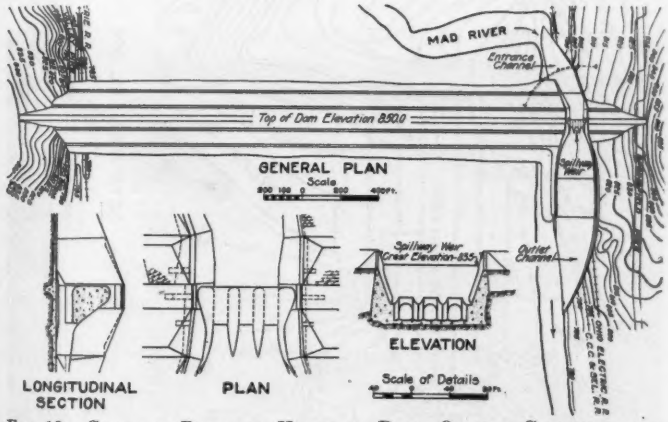


FIG. 10. GENERAL PLAN OF HUFFMAN DAM, OUTLET CONDUITS, AND SPILLWAY; AND ENLARGED PLAN, ELEVATION, AND LONGITUDINAL SECTION OF COMBINED CONCRETE SPILLWAY WEIR AND OUTLET WORKS.

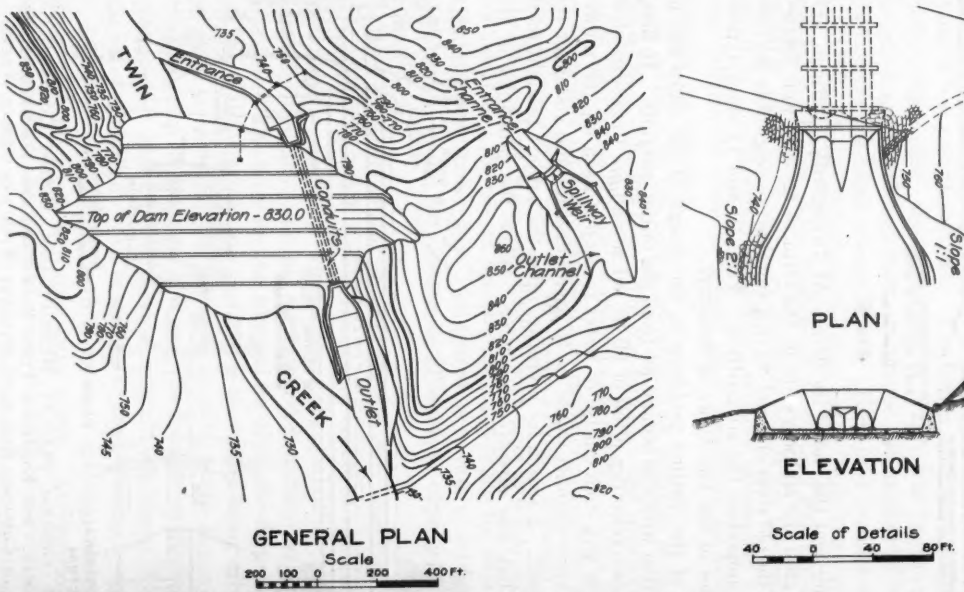


FIG. 11. GENERAL PLAN OF GERMANTOWN DAM, OUTLET CONDUITS, AND SPILLWAY; AND ENLARGED PLAN AND ELEVATION OF LOWER END OF OUTLET WORKS.

hydraulic pump were looked upon as the solution of the problem, the difficulty lay in so fashioning an outlet from the conduits that these principles would properly function in practice. Theoretical conclusions were not to be entirely relied upon without corroboration from experimental sources. Accordingly, a hydraulic laboratory was established upon the estate of Col. E. A. Deeds, president of the board, and it was largely through his generosity that the facilities for conducting the investigations were available. A model of the conduits of one of the dams was constructed to scale, and various types of outlets were experimented with under different conditions of flow. Baffle piers, similar to those at the Gatun Dam, were tried with various modifications; devices for spraying the water into the air and others for turning the streams against each other were studied, but the conclusion was finally forced upon those conducting the experiments that the most practicable method, under the conditions, of dissipating the energy of swiftly flowing water lay in the hydraulic pump. The shape of outlet adopted as the result of these studies consisted of a flaring basin, confined by high concrete walls, with a bottom sloping away from the outlet in steps, terminating in two baffle walls or weirs. A general idea of the arrangement may be had from an inspection

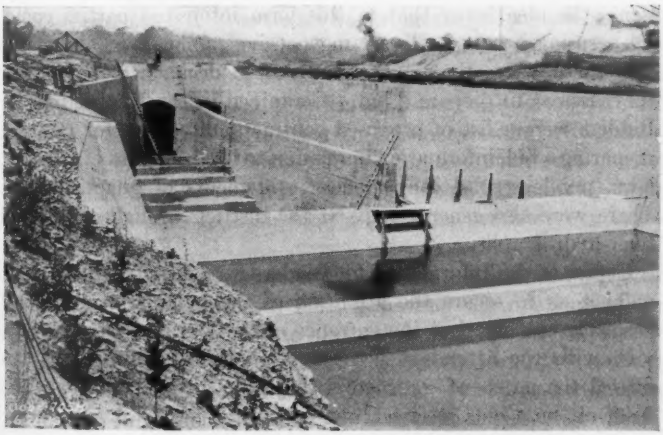


FIG. 12. OUTLET FROM ENGLEWOOD CONDUITS.

of Fig. 12. A full discussion of the foregoing experiments has been published as Part 3 of the Technical Reports issued by the Miami Conservancy District.

Construction.

Information for Bidders. Throughout the preparations for construction the thought was kept firmly in mind that if intelligent bids upon the work were desired as complete information as possible in reference to conditions to be encountered should be available. No haphazard guesses would be welcomed, but only such figures were desired as represented the mature judgment of experienced persons, based upon a thorough knowledge of working conditions and representing a square deal to both contracting parties. The fact that industrial conditions, due to the war, rendered it inadvisable to do the work by contract did not in the least detract from the usefulness of the assembled data, for the information available has proven of inestimable value to the engineering force in the planning and supervision of the work.

As a preliminary to inviting contractors to bid on the construction work, a pamphlet entitled, " Information for Bidders " was published as a separate volume from the contract and specifications, the idea being that in this form interested parties could, by perusing a comparatively inexpensive publication, obtain the necessary information to enable them to decide whether or not they desired to prepare a bid. Contained in the Information for Bidders were a list of proposed contracts, directions for properly preparing a bid, information in relation to local supplies of material, laws, public service conveniences, statements of quantities, etc. There were also general maps of the district, rainfall charts, and river hydrographs.

Copies of the Information for Bidders were distributed in such a manner as to secure the attention of the maximum number of desirable bidders; but the entrance of the United States into the war, with the attendant labor and material conditions, so unsettled the minds of contractors that only a few submitted bids. And, of those bids received, one only, a proposal for levee work, was in such form as to warrant acceptance.

Organization. As a natural result of the inability to close satisfactory contracts, the board decided to proceed with the work by force account. The organization was to be under the supervision of A. E. Morgan, — who as president of the Morgan Engineering Company had been in charge of the project from its inception, — chief engineer, and Chas. H. Paul, assistant chief engineer, with a division engineer and the necessary engineering assistants and clerical forces at each dam.

But it was desired to preserve as fully as should seem advisable the usual functions of contractor and engineer. To do this the office of construction manager was created. An effort to secure the very best talent available for this important post resulted in the appointment of Chas. H. Locher, a contractor of national reputation, who needs no introduction to the members of this Society. Mr. Locher's wide experience and resourcefulness have proven of inestimable value to the work. In practice it has developed that the relations of engineer and construction manager exist more in the nature of a copartnership, there being no tendency to place any hard-and-fast limitations upon the duties of either. So well has this plan of organization functioned in the year and a half of construction to date that no change of any sort has even suggested itself.

Specifications. A separate set of specifications for each contract was not written. Such procedure would have resulted in considerable duplication. Instead, the entire construction program was analyzed into classes of work, and each class given an item number. Specifications relating to each item were written and assembled into two volumes, one for the five dams and one for the channel improvement projects at Dayton and Hamilton. Only such items as were applicable to the particular work were included in each volume.

The specifications fall into three parts: — first, the General Conditions, Sections 0.1 to 0.57, governing the relations of the contractor to the district, to the public, and to his employees; second, the General Specifications, Sections 0.58 to 0.105, defining and classifying the most commonly used materials, and indicating in general how the work shall be done; and third, the Detail Specifications, Sections 1.1 to 90.2. The Detail Specifications by

supplementing the Agreement, General Conditions, General Specifications, the Estimates, and the Drawings, define in detail how each kind of work shall be done, and how it will be measured for payment.

The different kinds of construction work to be done and of materials to be furnished are classified into items, an item meaning a certain kind of work to be done, or material to be furnished, in a certain definite manner, regardless of its location. Each item is designated by a name and number, the numbers running from 1 to 90, as Item 2, Clearing and Grubbing, or Item 51, Reënforcing Steel. All sections relating to any item bear the number of the item as an index number before the decimal point. For instance, Item 50 covers cement, Section 50.1 gives the requirements as to brands, Section 50.2 specifies the manner of delivery and storage, Section 50.3 covers inspection, tests, etc., and Section 50.4 specifies the methods of determining quantities of cement for payment.

All item numbers with letter "a" affixed refer to work below mean low-water level as indicated on the drawings. For instance, Items 41 and 41a include concrete in outlet works, spillways, retaining walls, bridge piers, and other similar structures, above and below mean low water, respectively. The same item may be met on various parts of the project. Wherever in the estimates or on the drawings "Item 41" is indicated, regardless of whether it occurs in channel improvement at Hamilton, or in the construction of the Englewood Dam, or in some other construction, the work to be done is the placing of concrete in accordance with the Specifications under Item 41, supplemented in all cases by the General Specifications, which apply to all items. Item 41a refers to the same kind of construction as Item 41, except that the work is located below mean low water, as shown on the drawings.

In brief, the General Conditions and General Specifications relate, in so far as they are applicable, to all work. The estimates and the drawings indicate under what item or items any particular part of the work is to be done, and specifications for that item give the necessary further directions for doing that particular work.

An attempt was made in the phraseology of the specifications to depart from the time-honored custom of making the contractor responsible for everything under the sun. In the first place, it was

the intention of the authors of the specifications that the obligations of both contracting parties be defined with such clarity that any possibility of wrangling or future litigation be eliminated. Clauses were not inserted for no better reason than that they occurred in some other "standard" specification. Obligations, which it was never intended that the contractor should assume, were not embodied, with the idea that they might, sometime, come in useful. No attempt was made to endow the engineer by edict with autocratic powers, regardless of what the courts always say about such procedure. In short, the fact was constantly held in mind that there were two honorable contracting parties, each with his rights and obligations, and, while the engineer was shorn of none of the authority or right of decision necessary for the successful prosecution of the work in accordance with the desired standards, such power was not given to him arbitrarily, but in strict accordance with well-defined principles clearly stated in the contract and specifications.

Particular attention was paid to the form of bond, and, while no requirements were embodied that may not be found in the standard forms in use by leading bonding companies, the form of bond adopted was designed to provide the greatest protection to the district without imposing upon the securities any unreasonable obligations.

To give the fullest possible opportunity to local bidders, who might not in some cases be possessed of great resources, the proposed work was divided into as large a number of separate contracts as seemed compatible with rapid progress and efficient execution. At the same time, in order not to discriminate unduly against the larger contractor, provision was made to receive bids upon different contracts in combination. By this means a contractor possessed of larger means and equipment could bid upon the work in large units without incurring the danger of being awarded only small or isolated parts of the work.

To fully draw upon the industrial resources of the community the following notice was embodied in the advertisement:

"*Notice to Subcontractors.*

"The larger contracts to be let contain numerous smaller pieces of work for which the main contractor may not be equipped, and which he may desire to sublet. The chief engineer of the Conservancy District would be pleased to hear from any persons or firms who would be in position to take any of these subcontracts, and will put them in touch with those who will bid on the larger contracts as a whole. On the reverse side of this sheet is a blank form which may be filled out by those interested. Some of the kinds of work which may be included in these subcontracts are: . . ."

(Here follows a list of work such as a small contractor might undertake, and forms for filling in his resources, qualifications, equipment, etc.)

Power. Owing to the location in the vicinity of Dayton, convenient to the five dams, of a large commercial electrical power plant, this form of power was decided upon for use wherever feasible. It is expected that the Conservancy demand will be upward of 8 000 h.p. To distribute this, the power company set over 2 000 poles and strung more than 200 miles of copper wire. The greatest distance of transmission is to the Lockington Dam, 40 miles from the power station. Alternating current at 6 600 volts is generated at the power station, transmitted at 33 000 volts, stepped down to 2 300 volts at each dam-site substation, and distributed to the motors at 440 volts and to the lighting system at 110 volts. An exception is made in the case of the motors for the large dredge pumps, which receive their current at 2 300 volts. All electrical power is 3-phase, 60-cycle, alternating current. The rate paid for current is in accordance with a sliding scale based upon quantity used and the maximum demand. At Englewood, using 500 000 kw.-hrs. monthly, the rate has been slightly under 1.6 cents per kw.-hr.

Plant. One of the serious questions involved in the starting of a large construction job in war times was the assembling of the necessary plant. However, the War Department declared the work an essential war industry and gave favorable priorities. Their justification for doing this lay in the fact that the territory to be protected by the proposed improvement embraced a vast number of important manufacturing plants for war materials as well as a large aviation field and training station for fliers. By this means

it was possible to secure without serious loss of time items of plant and equipment, the lack of which otherwise would have made it impossible to begin active operations.

Camp. As only the most meager housing facilities existed in the vicinity of the proposed dams it was decided that proper provisions should be made by the Board for the comfort and welfare of its employees. And it was felt that no mere collection of shacks would suffice for the class of labor it was hoped to attract. Accordingly the topography of the land available for camp purposes was carefully studied, and an expert in city planning retained to lay out at each dam a village which, after construction should end, would have permanent value. The result has been most satisfying. At each dam is an attractive village, with its cottages, schoolhouse, mess hall, store, first-aid station, and community hall. The latter was usually some existing building adapted to the purpose. Large barns or tobacco sheds were remodeled into bunk houses, where the single men can find living accommodations. In general, the bunk houses are arranged with a long corridor, off which are the rooms. Each room holds a double-decked steel cot, and every room has an outside window. All cottages, bunkhouses, etc., are provided with shower baths. The camp has a modern sewer system. The result has been that employees are provided not only with a house but with a home, and instances have come up where attractive offers of employment elsewhere have been refused by residents of the camp who have preferred not to move.

The community spirit at each of the dam-site villages is evidenced by the fact that each camp has its local self-government. All residents of the camp are eligible for membership to these associations. With various modifications, the commission-manager form of government is used. All matters of local interest, including general welfare, are decided by the community government.

At each of the dam sites a school teacher is employed by the Board, and a schoolhouse provided. The schools are following the most advanced methods, and are establishing a reputation for themselves. Applications for enrollment have come even from residents of the neighboring country who have no connection with the Conservancy work.

Soil Stripping. An early operation in the construction of the dams was the soil stripping. The specifications required the removal of all vegetation, stumps, roots one inch or more in diameter, and any unsuitable matter. The method of doing this at Englewood will be described as fairly typical. Excavation was by means of an elevating grader of standard make, hauled a portion of the time by a large tractor and the remainder by 16 mules, four in lead, six on pole and six in rear. These were served by 14 three-up bottom-dump wagons. The material was stored in windrows just outside the toes of the dam, to be later spread over the graded slopes as soil dressing.

Work was done during the summer months. There were 56 possible working days and 47 actually worked, a loss of time of 16 per cent., due to weather. The average loaded haul was from 150 to 200 ft. The material moved aggregated 45 000 cu. yd., and the depth of cut was about 7 in., or one plowing. The daily yardage moved averaged 945 cu. yd. working a 10-hr. shift.

Outlet Works. At each of the dams attention was focused first on the construction necessary to divert the river. This was accomplished at Englewood and Germantown by means of the concrete outlet conduits; at Taylorsville, Huffman, and Lockington the bottom and sidewalls only of the spillway are being built, leaving the weir to be placed later and forming a large flume which permits the unobstructed flow of the river.

The Englewood outlet structure has a total length of 1 060 ft., of which 709 ft. is a double-barreled covered conduit. A cross-section at its maximum thickness, under the center portion of the dam, is shown in Fig. 13. As the conduits approach the toes of the dam, with the depth of cover correspondingly reduced, the thickness of crown and sidewall are gradually lessened, becoming 15 in. and 18 in., respectively, at the downstream toe, and 18 in. and 24 in., respectively, at the upstream toe.

During the construction period the full opening of the conduits will be utilized for the flow of the stream, but when the dam shall have reached such a height as to be safe from overtopping from floods the lower portion will be filled with compact sand and gravel and the permanent floor constructed, reducing the area of the waterway to its figured size.

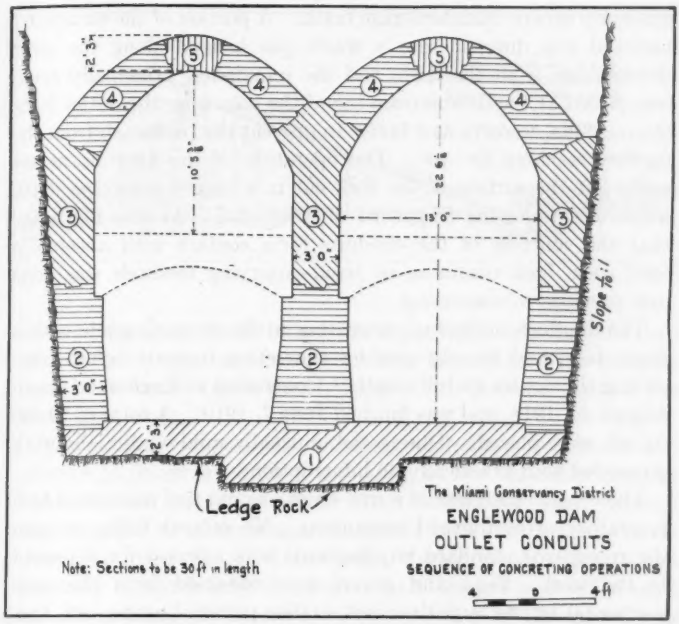


FIG. 13.

The conduits are founded entirely in rock, known geologically as Cincinnatian Formation. It consists of layers of hard, highly fossilized limestone, ranging from one to four inches in thickness, interstratified with layers of hard clay or soft shale. Upon exposure to the air the clay and shale content rapidly disintegrates. In the geological scale the formation is found in the upper reaches of the Ordovician (Lower Silurian) Period.

Excavation on the outlet works was begun May 10, 1918, and continued to November 13, 1918, during which time 8 000 cu. yd. of earth and 58 000 cu. yd. of rock were excavated. The material was handled by means of a 115-ton steam dragline excavator of standard make, equipped with an 85-ft. boom and a 5-yd. bucket. The machine would back along the line of the conduit, digging behind itself as it moved, and depositing the material into 12-yd.

air-dump cars on standard-gage track. A portion of the excavated material was dumped into a waste pile located along the river downstream from the dam, and the remainder, principally rock, was placed at the downstream toe of the dam near the outlet from the conduits, to serve as a buffer to prevent the backwash from the outflow reaching the toe. The operation of the dragline necessarily left the surface of the rock cut in a ragged condition, with numerous projecting fragments of loose rock. As it is necessary that the concrete of the conduits form contact with absolutely solid rock, final trimming by hand-quarrying methods was done just previous to concreting.

The dragline method of excavating works down to grade with a single face, and thereby enables concreting to start before completing the cut for its full length. Concreting at Englewood began August 10, 1918, and was finished June 7, 1919. A total of 19 000 cu. yd. were placed. Due to the unusually mild winter, the work proceeded with practically no interruption.

The cement used was of a well-known brand and was tested by a laboratory of established reputation. No cement failing to pass the recognized standard requirements was released for shipment to the work. Sand and gravel were obtained from the main borrow pit by the large draglines sending material to the dam, and, part of the time, by a smaller dragline operating solely for that purpose. The material was hauled in the regular 12-yd. dump cars to the combined screening and mixing plant located near the inlet end of the conduit. Here the aggregates are separated into three sizes, — coarse gravel, from 1½ in. to 3 in. diameter; fine gravel, from ¼ in. to 1½ in. diameter; and sand, all material from ¼ in. down. The arrangement of the plant is shown in Fig. 14. The separation of the coarse aggregates into two sizes was not so much for the purpose of combining them later into some ideal grading curve but rather to prevent the segregation which takes place in the bin, particularly when it is drawn well down, from delivering to the mixer a whole batch of improperly graded stone. This arrangement worked out very well in practice, as it enabled the grading to be varied at will. An instance of this occurred in starting a day's run, where it was desired to use the smaller stone until a cushion of concrete had been deposited into which the

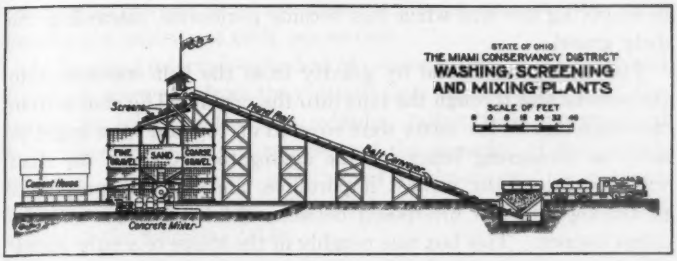


FIG. 14.

coarser aggregate could imbed itself properly. Having the two sizes of coarse aggregate in separate bins also enabled the concrete in the arch sections to be proportioned with a preponderance of the small-sized stone.

The mineral composition of the aggregates was well known, — principally limestone, with a sprinkling of the Canadian granites brought down by the glaciers. And the concrete- and mortar-making qualities of these aggregates had been satisfactorily ascertained by many tests. Accordingly, during construction it was necessary to watch only the cleanliness of the gravel and the sand and the grading of the sand. The condition of the gravel was apparent by inspection. Each day a sample of sand was taken as it entered the mixer. A part of this was washed to determine the silt content, and a portion was run wet through the Universal Tester and its mechanical analysis plotted on a whiteprint upon which appeared the mechanical analyses of all sands tested during the preliminary investigations and found acceptable. Not much concern was felt on this score, as no sands investigated failed to equal standard sand, and by far the greater number exceeded it in the 2-in. mortar cubes. The careful inspection of aggregates developed one feature in the gravel-washing plant, a failure to detect which would have led to unfortunate results. In a plant of this kind, where the material goes from the screens into the bins and thence direct into the mixer, it was found that the washwater clinging to the separate stones carried in suspension an infinitesimal amount of silt which settled in the bottom of the bin and, in time, caused a deposit of mud which coated the stones. The remedy lay

in emptying the bins when this became noticeable, discarding the dirty gravel.

The aggregates flowed by gravity from the belt conveyor into the screens and through the bins into the mixer. The chutes from the stone bins to the mixer were covered on top and were gaged to serve as measuring boxes for the aggregates. Gaging the sand was deemed of the utmost importance, and for this purpose a measuring box was interposed between the sand chute and the mixer hopper. This box was roughly in the shape of a cube standing on its corner, with the top and bottom corners cut off, the top to fill and the bottom fitted with hinged doors to empty. In this manner the area of the mouth was made as small as possible and, as the proportion of sand called for a full box, any slight inaccuracy in striking off would have little effect on the resultant volume.

A refinement entering into the construction of the conduits was in the adjustment of the amount of cement entering into the concrete used in the various parts of the structure. For instance, in the faces of the retaining walls of the inlet and outlet, at the level where the water will stand during the greater part of the winter, a richer mix was used for a foot or so back from the face. This was to give the concrete at this particular place additional resisting qualities against the disintegrating tendencies of the freezing water. Similarly, in all wide retaining walls, the faces of which are exposed to swiftly flowing water, more cement was used in the mixture along the face than in the backing of the wall.

The foregoing adjustment of mixtures was, of course, in addition to the proportions normally determined upon for various parts of the structure, depending upon the work the particular concrete is called upon to do. Inasmuch as the cement is by far the most costly ingredient entering into the mixture, it is obvious that its content shall be as low as practicable without chancing to sacrifice any of the qualities essential in the finished product. Following this reasoning a number of standard mixtures were selected. In all cases the amounts of sand and gravel were constant; the variation in the mix being governed by the number of sacks of cement added. Thus, a 5-bag mix gave proportions by volume of 1:2.8:5.6 and an 8-bag mix gave proportions of 1:1.75:3.5. The latter mixture was used in the covered portion of the conduits, where the

concrete in extreme flood conditions will be in contact with water flowing at a velocity of 60 ft. per second.

At frequent intervals cylinders of concrete, 6 in. in diameter and 6 in. long, were cast from the material as it was being placed. The reason for selecting this size cylinder, rather than the standard 8 by 16 in., was that it represented the capacity of our testing machine. The cylinders were stored in damp sand or sawdust until ready for breaking. The results of the tests at Englewood appear in the following table:

Sacks.	Proportions.	Number of Specimens.	Compressive Strength in Lbs. per Sq. In. at 3 Months.
5	1:2.8:5.6	15	2 280
6	1:2.33:4.66	30	2 573
7	1:2:4	6	3 300*
8	1:1.75:3.5	9	3 300*

* Exceeded capacity of machine.

When it is considered that the concrete will not be called upon to sustain stresses in excess of 500 lb. per sq. in., it will be seen at a glance that no apprehension need be felt on this score as to the safety of the structure. The average cement factor for the entire 19 000 cu. yd., in bbl. per cu. yd., was 1.57.

In order to provide for internal stresses in the concrete due to temperature and shrinkage, and partly to facilitate casting, the conduits were built in 30 ft. sections longitudinally and brought to their full height in several separate operations. This will be made clear by reference to Fig. 13. Collapsible wooden forms, which could be used repeatedly throughout the life of the concreting operations, were devised by the designing division. For the retaining walls, panels, cantilevering from the finished concrete as the walls progressed upward, were used. All forms gave excellent service and were still good at the end of the job.

Concrete was mixed in one-yard batches, the mixer emptying into side-door hopper cars on 3-ft. gage. The concrete track ran close to and parallel with the conduit excavation and was at such elevation that the greater portion of the concrete could be chuted directly into place. The concrete cars were hauled by a 3-ton gasoline locomotive, which gave uniformly excellent service throughout. In fact, this locomotive was one of the most pleasing items of plant on the job.

FIG. 15. ENGLEWOOD OUTLET CONDUITS.
Showing also old river bed prepared for embankment.

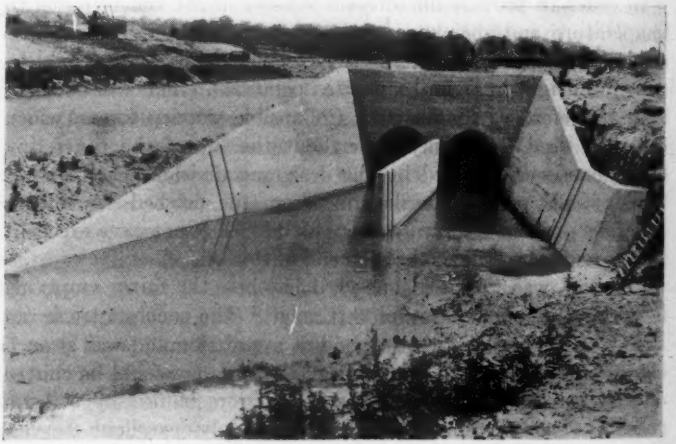


FIG. 16. ENTRANCE TO ENGLEWOOD CONDUIT.

The outlet conduits at the Germantown Dam are 546 ft. long, exclusive of the inlet and the outlet, and contain 15 000 cu. yd. of concrete. Their construction followed very closely the methods in use at Englewood. No unusual conditions were encountered, and the structure is now completed.

At the Lockington Dam the problem was entirely different from Englewood and Germantown. While the latter two structures are of the covered-conduit type, the Lockington outlet works consist of an ogee weir, through the lower portion of which are two openings, 9 ft. wide and 9 ft. 2 in. high, for the normal river flow. For stream-control purposes during construction the bottom and side walls only of the structure were built, leaving the spillway weir to be placed after the embankment of the dam shall have reached sufficient height to be safe from overtopping during flood flows of the river.

The Lockington outlet works are founded upon Cedarville limestone. The top of ledge rock was close to grade, and slight excavation only was required to provide a suitable foundation. Some grouting was necessary, however, owing to the presence of cavities, such as are commonly found in limestone of this sort.

The structure as built to date contains about 28 000 cu. yd. of concrete. Excellent sand and gravel for concrete were found in the excavation, the material being handled by means of a large dragline. The screening and mixing plant were essentially the same as those for all five of the dams and mentioned in more or less detail in the description of the Englewood conduits. The concrete was transported in 1¼-yd. bottom-dump buckets on platform cars drawn by a gasoline locomotive and placed by two large steel derricks. Wooden cantilever panel forms were used.

The construction of the outlet works at the Huffman Dam is, in all essentials, similar to that at Lockington. The structure is similar and the methods followed do not differ sufficiently in detail to merit separate mention.

The Taylorsville outlet works are of the ogee weir type, similar to Lockington and Huffman. For their construction they require, however, very much more excavation. This work is now in progress. The quantities to be moved aggregate 500 000 cu. yd. earth and 350 000 cu. yd. rock (Cincinnatian Formation). At

this writing (September 1) the excavation is 40 per cent. completed. The material is being handled by a large electric dragline, equipped with a 100-ft. boom and a 3½-yd. bucket and loaded into standard-gage 12-yd. air-dump cars for transportation across the river, where the rock is dumped into the toes of the dam. It is expected that concreting at Taylorsville can be started about October 1.

Hydraulic Fill. The total embankment in all five of the Conservancy dams will aggregate in the neighborhood of 8 000 000 cu. yd. Practically all of this will be placed by the hydraulic method.

The first important consideration in the program of construction was the problem of stream control. It must be kept in mind that these dams are situated above large centers of population, where any sudden release of impounded water would spell disaster. Therefore the sequence of operations must be so planned as to be safe beyond a reasonable doubt, even should a repetition of the great 1913 flood occur. This is done in two ways, depending upon the type of outlet works. At Lockington, Huffman, and Taylorsville the outlet works, as previously stated, are simply openings through the lower portion of the spillway weir. It is, therefore, a simple matter to construct the bottom and side walls of the structure, making an admirable flume for the passage of water. The weir itself is not built in until the dam has reached a safe height. For the covered-conduit type of outlet works, as at Englewood and Germantown, however, the stream-control problem is vastly more difficult. Here it is necessary to retain the original waterway or provide an artificial one until such time as the adjacent portions of the dam can be carried up to an elevation of safety, and subsequently to make the closure during the season of low flows. At Germantown the problem is simplified by the narrow valley, and the yardage involved in raising the embankment clear of the danger point is sufficiently small to permit the river closure to be made this season. In fact, the work is now going on. These closures are, of course, greatly facilitated by the temporarily increased capacity of the conduits, as explained earlier in the text.

At Englewood the stream-control problem is somewhat complex. The country is so flat that a closure entirely across the river valley

during one low-flow season is not to be thought of. The alternative, therefore, lies in what amounts virtually to building the dam in sections. The first season a cross dam is built on the east bank of the river. This cross dam is nothing more or less than a short section of the main embankment built from toe to toe, to serve as a retaining wall for the end of the hydraulic fill. Where this end dam lies within the outer portions of the main embankment it is built up of porous material; where it crosses the middle portion of the main dam impervious material is used. Thus the composition of the main dam from end to end is not interfered with by the fact that the cross dam is interposed. The cross dam is carried up only fast enough to keep well clear of the hydraulic fill. Where within the outer portions of the main dam the material for the cross dam

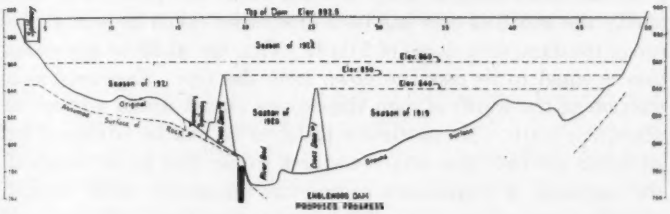


FIG. 17.

is pumped into place integral with the main hydraulic fill. The central portion is rolled in 6-in. layers, using a 12-ton steam roller.

With the cross dam in place to elevation 840, something over a million yards of hydraulic fill can be pumped without disturbing the river channel. This is a good season's work. In the meantime west of the river a temporary spillway, guarded on the east by a cross dam carried to elevation 850, will be constructed, and next April, with about eleven months of immunity from severe floods ahead, the river closure can be made and the hydraulic fill carried up to elevation 850. The third season sees a comparatively easy closure of the temporary spillway, and no further worry from flood flows, even should a repetition of the 1913 flood occur. The dam should be completed the fourth season. An inspection of Fig. 17 will make the foregoing program clear.

At all the dams the material for the hydraulic fill comes from the

river valley upstream and consists of a modified glacial drift. A slight exception to this occurs in the case at Taylorsville, where glacial till from the excavation for the spillway, so long as it lasts, is being pumped into the dam. The details of this process will be referred to more fully later.

In cross section the outer portions of the dam are composed of cobbles, gravel, and sand, and the central core of silt and clay. In the interests of safety the width of core in all the dams is confined to comparatively narrow limits. Such a procedure does not entail any particular hardship, inasmuch as the modified drift from the borrow pits contains roughly the desired proportion of clay. At Taylorsville, however, where the dam at present is being built of glacial till from the spillway excavation, the proportion of clay is so great as to necessitate some wasting from the pool. For simplicity the width of core has been arbitrarily taken as zero at the top of the dam, with slopes of 2 on 1. Thus the width at any elevation is equal to its distance down from the top. Expressed as a fraction of the width of dam the core as placed would amount to about one sixth. No particular justification can be advanced for adopting precisely this ratio, excepting to say that in the minds of the engineers it represented a structure eminently stable against sloughing and at the same time one that contained sufficient core to be impervious against impounded water. Very conveniently the adopted proportion of core coincides with the " fines " in the material from the borrow pits. This may not be entirely a coincidence. Hydraulic fill is in progress at this writing (September 1) at Englewood, Taylorsville, Germantown, and Lockington dams. Huffman has a big railroad relocation problem on its hands, and will not be ready to pump dirt much before next year.

The Englewood borrow pit is located upstream from the dam, as will be seen in Fig. 18. The material is excavated by means of two 115-ton dragline excavators, one electric and the other steam, equipped with 85-ft. booms and 4½-yd. buckets. The draglines are ranged along the same track, one about 1 000 ft. in advance of the other. An interesting comparison is offered as to the relative merits of steam and electricity as power for machines of this type. With electricity at slightly less than 1.6 cents per kilowatt-hour, the steam dragline is somewhat more expensive. The latter is

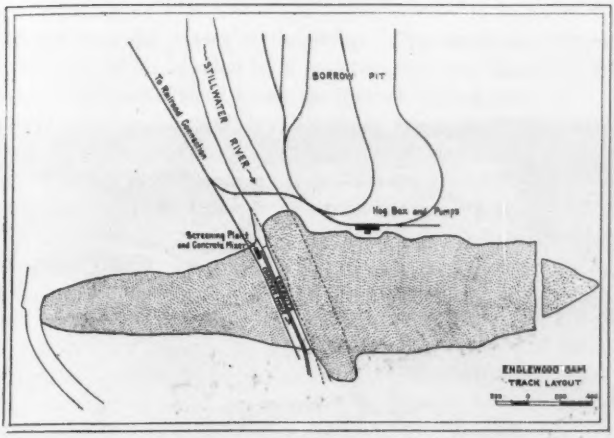


FIG. 18.

more rapid in operation, but the cost of coaling runs the unit cost above that of the machine using electrical power. The depth of face in the pit averages perhaps 15 ft., and the draglines load into standard-gage 12-yd. air dump-cars. Under these working conditions each machine can comfortably move from 150 to 180 cu. yd. per hour. A double-track system is arranged, with suitable crossovers, in such a manner that no interference occurs in the handling of trains.

There are four trains from the borrow pit containing seven cars each, which are handled by 40-ton locomotives. They climb a 2-per cent. compensated grade into a trestle 175 ft. long, paralleling and close to the upstream toe of the dam. From the trestle the cars dump into what has been given a name more practical than euphonious,— "the hog box." One standing at a point of vantage and watching the material going in and being devoured by the sluicing giants can readily see the application. The hog box is essentially a trough 150 ft. long and 27 ft. wide, ranged alongside the track from the borrow pit which, at this place, is carried on a pile trestle. The floor of the hog box is 13 ft. below the rail and cones at approximately 4 per cent. to an opening in the opposite side from the track. The opening discharges into revolving screens through

FIG. 19. ENGLEWOOD DAM.
Old river bed in foreground, Cross Dam and Hydraulic Fill in middle distance.

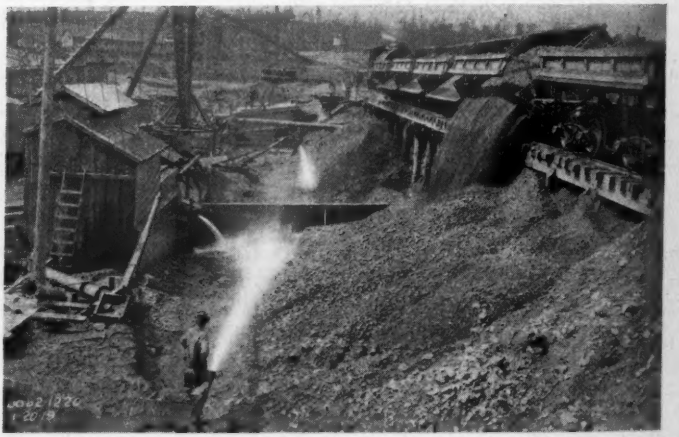


FIG. 20. ENGLEWOOD DAM, HOG BOX, AND PUMPING PLANT.

which the material passes to the sump. The sump is a concrete well, 8 ft. by 16 ft., divided by a partition into two chambers 8 ft. square. The floor is 16 ft. below the floor of the hog box.

The material as dumped from the trains into the hog box may be dry or wet, according to whether the draglines happen to be digging above or below ground-water level. As the material lies in the hog box, it is washed through the revolving screens into the sump by means of two hydraulic giants or monitors, one at each end of the hog box. Pressure for this sluicing water is furnished by two 10-in. centrifugal pumps, operating at a speed of 1140 r.p.m. and each driven by a 100 h.p. motor. The pressure is maintained at approximately 60 lb. and the jet is directed through a 3-in. nozzle.

The revolving screens are the product of several rejected schemes for eliminating the oversize rock from the material being fed to the dredge pumps. At first, sloping gratings of several types with square openings were tried. These were fairly satisfactory when the material was not coming too fast or when there was not too great a proportion of clay lumps. At such times the tendency was for the gratings to clog. Furthermore, each grating required the services of three men, clearing away the material. But the revolving screens seem to have effected a complete and simple solution of the rejection of oversize. The screens are cylindrical in shape, 4 ft. in diameter, have an effective screening length of about 9 ft. and are pierced with 6-in. circular holes in one case and 6½-in. holes in the other. The latter size is in the last screen installed and is an attempt to use the largest size openings without choking the dredge pumps. While the 6½-in. holes are satisfactory it is not known as yet whether or not this size can safely be increased. The screens pitch ½ in. to the foot. The first screen installed was given a speed of 14 r.p.m. but in its companion, installed later, the speed has been reduced to 9 r.p.m., and seems to give, if anything, more efficient service. Each screen is operated by a 7½-h.p. electric motor, belt connected, the reduction in speed being accomplished through a countershaft. From the screens the acceptable material drops directly into the sump, while the oversize rock goes out of the end into bottom-dump buckets which are hoisted out with a stiff-leg derrick and dumped into a standard car in which they are hauled away to the downstream slope of the dam. Not

only do the revolving screens serve to reject the oversize rock but, in addition, they fulfill another most important function. The tendency of the giants, even with the most skillful handling, is to wash the material into the sump in masses. Thus, one minute the dredge pumps would be handling comparatively clear water while the next they would be staggering to clear themselves of an overload. The action of the revolving screens, however, tends to rectify this irregular feed and to deliver the material to the suctions of the dredge pumps in a uniform flow. It is of the utmost importance that this delivery of the mud to the pumps be as uniform as possible. A neglect of this precaution has a most dire effect upon the output.

Directly beneath each screen is an inverted truncated pyramid with an opening 2 ft. square directly above the suction of the dredge pump. The object of this is to remix the fine material passing one end of the screen and the stones passing farther on. The suctions from the dredge pumps are inclined at an angle of 45 degrees from the vertical, and in order to lead the material to them along the easiest lines the floor is shaped as an inverted pyramid. It has been found that with a flat floor the mud has a tendency to pile up until at some point a great mass will slough off and bury the suction. Then comes the plug and a vexatious delay until the suction pipe is cleared.

The business end of the hydraulic-fill plant is the dredge pumps. At Englewood the present installation comprises two 15-in. centrifugal pumps, designed for 150-ft. head, operating at a maximum of 505 r.p.m. and each driven by a 500 h.p. slip-ring induction motor. These pumps are made of cast manganese steel, containing perhaps 5 or 6 per cent. of manganese (although the makers have not disclosed this). As yet this particular alloy seems to be by far the best fitted for standing the abrasive wear of sand and gravel. The shell of these pumps is from $2\frac{1}{2}$ to 3 in. in thickness, depending upon the place. An item of the utmost importance is the design of the impeller, a matter which is complicated by the range of head against which the pump is called upon to operate. For instance, at Englewood the dredge pumps are working under heads which at the beginning are not more than 25 ft., but which are steadily increasing until a maximum of 150 ft. shall be reached, at

which point a booster pump will be inserted in the line. To compensate for this variation, different size runners are being tried, a smaller one for the lower heads and increasing in size as the heads shall increase. This arrangement is adapted to develop more fully the power of the motors. With the large runner against low heads a large percentage of horse power is wasted in overheating the grids. Diameters of runners of from 38 in. to 46 in. are being tried, but as yet it is too early to state results. The matter is, however, one of vital importance and will be carried along to definite conclusions.

The life of one of the manganese steel pumps as at present designed, pumping sand and gravel, is slightly less than 200 000 cu. yd. At Englewood the second pair of pumps is now in service, but the designers are making modifications in design for future deliveries, from which are expected better results. The impellers show wear at 50 000 cu. yd., but can be used, with doubtful efficiency, for perhaps 100 000 cu. yd. The consensus of opinion among those studying the operation of the pumps is that it does not pay to use equipment after it is badly worn. Economy is better served by scrapping the old shells and runners the moment they show signs of letting down. Inasmuch as the dredge pumps are the neck of the bottle, and the entire organization is succeeding in its purpose only to the extent that the pumps are functioning, it is obvious that they should operate at the highest pitch. To increase the life of the impellers, renewable shoes, for the wearing parts, are being tried.

The operation of the dredge pumps and monitor pumps requires about 31 c.f.s. of water. The location of the sump is 450 ft. from the river. Rather than pump the water this distance a 4-ft. corrugated-iron culvert was laid, through which the water flows by gravity. Near the sump a concrete well was built in the line to serve as a sump for the monitor pumps. Each of the two monitor pumps handles 2 000 gal. per min. The nominal capacity of each dredge pump is 7 000 gal. per min., which is the amount to be provided for, inasmuch as the discharge from the monitor pumps feeds into the sump.

The dredge pumps pick the material up from the sump and discharge it to the dam through 15-in. pipe. Where the pipe line runs

FIG. 21. ENGLEWOOD DAM.
Hydraulic Fill, discharge from 15-in. dredge pipe.

FIG. 22. ENGLEWOOD DAM.
Hydraulic Fill. "Drop-off" which takes place just inside central pool. Water in pool has been purposely lowered several feet.

up the side of the dam, and is therefore more or less permanent, the heaviest class of standard cast-iron flanged pipe is used. For the shore lines, however, where the pipes are changed for each run, a lighter pipe than the cast iron — one that can be handled with rapidity and ease — is required. For this purpose one of the large rolling mills is manufacturing a special welded manganese-steel pipe. This metal contains 0.50 to 0.60 per cent. carbon and 0.60 to 0.70 manganese, which limits are imposed by the rolling

FIG. 23. ENGLEWOOD DAM HYDRAULIC FILL.

process. The pipes are slip joint, i.e., have a slight bell on one end, and are held together by wire stretched over hook lugs. The thickness of shell is 11/64 in., the pipes are in 16-ft. lengths and weigh 28.83 lbs. per lin. ft. It is not known just what the life of these manganese-steel pipes is, for the very good reason that, to date, none has worn out. The greatest yardage that any of the pipes have passed to date is about 300 000. Riveted steel pipe, made from ordinary steel plate containing 0.10 to 0.20 carbon, proved very shortlived. Claim has been made that the manganese pipe will last ten to fifteen times as long as 0.15 carbon steel, and this may prove to be so. To insure an even wear around the circumference of the pipe, they are turned 120 degrees for each

new run. Observation shows that practically all of the solids flow within the lower third of the pipe, the upper two thirds being filled with water bearing only the lightest particles. Consequently, for a given run it is the lower portion of the pipe only which is subjected to any considerable wear. No difficulty is experienced in practice in doing this; one end of each pipe is numbered 1, 2, and 3, 120 degrees apart, and each time a line is relaid the pipes are revolved until the next number is uppermost.

The trick in pumping earth materials seems to lie in developing the consistent maximum capacity of the pumps and then feeding them uniformly to that capacity and no more. If the pumps are not receiving all the solids they can handle, money is being wasted. If, on the other hand, the pumps receive more than they can handle for any considerable time, a plug ensues and the entire pumping outfit spends many profane hours in clearing out the pipe,— not a pleasant or easy job at best. Of course, short overloads, if not too heavy, can be handled by the reserve power in the motor, but there is a limit to the length of time this reserve can be applied without injuring the motor, and also a limit to the amount this power can handle. The whole method involves a synchronizing of effort on the part of the monitor men and the pump runner. Either working without due regard to the other can waste efficiency or plug the system. If the pump man does not throw in an extra finger on the switchboard at exactly the same time that the monitor men are crowding the dirt, trouble ensues. At Englewood the first plan for coördinating the various operations consisted in establishing a control tower overlooking the hog box. Here were installed pressure and vacuum gages, electric-bell connections to pump man and monitor men, and connections with portable telephones at the ends of the pipe lines. By his electric-gong signals the foreman in the tower could direct operations,— signal the monitor men for more or less feed, as the case might be, or notify the pump man to increase his power. This was a big advance over anything tried before, but it had one weak spot,— the gages in practice did not always operate as swiftly or as surely as was desired. Sometimes the line would plug before the gages had given warning. But the difficulty has been solved by a very simple little device. The first sign of plugging in the pipe is manifested by a reduction of

velocity. This at once becomes apparent at the discharge from the pipe line by a slackening of the issuing stream. With this in mind the resident electrician rigged up a small attachment, consisting essentially of a steel clapper working on a hinge and forming contact at one end with an insulated wire running to the pump-house, and at the other end with the jet from the pipe. The theory of the contrivance is that, with a full jet issuing from the pipe, the clapper is pushed against the contact points and the circuit is closed, but as the jet falls the contact breaks and the circuit is opened. Connected in the circuit are incandescent lamps, one at each monitor and one at each pump. Thus the monitor men and the pump man are constantly and instantly informed as to the condition of flow through the pipe, and can govern themselves accordingly. This simple device has resulted in a marked increase in the output and has borne a large share in the elimination of plugs.

In building the dam the pipes are ranged along the outer portion of the fill. As the material builds up, pipes are added, a 16-ft. length at a time, until the end of the run is completed. The line is then taken apart and a fresh start made, each run being 4 ft. higher than the previous one. Upon issuing from the pipe the coarser material tends to settle first, leaving the finer to be borne by the flowing water toward the central pool. On reaching the edge of the standing water, or slightly farther, depending upon the velocity, all coarse particles are immediately precipitated on a slope of about 1 to 1. Beyond this, nothing is carried but silt and sand. It will be seen, therefore, that the width of core is dependent upon the width of pool, provided, of course, that the material being pumped contains a sufficient percentage of " fines " to make a core of the desired width. If more than this occur, the excess clay must be wasted with the outflow from the pool.

In advance of the pipe line, to prevent a portion of the discharge from flowing down the slope of the dam, a levee is thrown up. At Englewood this is done by means of 35-ton steam dragline excavators, mounted upon caterpillar tractors, one operating just in advance of each pipe line.

The slope of the fill from the pipe line toward the pool is dependent upon the coarseness of the material and the percentage of solids in the discharging stream. For the Englewood material

this slope ran uniformly at approximately 6 per cent. for several months. During August, however, with an increased output, the slope has jumped up to about 7.75 per cent. A small amount of the water entering the pool seeps out through the gravel, appearing as small springs along the toes of the dam. The greater portion, however, must be led away in some form of wasteway. The method in use at Englewood is to dig a ditch about 8 ft. deep at one end of the pool, following the contour of the hillside. In this ditch a small earth dam is built through which are laid some old 20-in. dredge pipe. A wooden paddle serves as a gate for each pipe. Each spillway, progressing up the hillside, serves two runs, or 8 ft. in elevation of the pool.

As previously stated, the material in the outer portions of the dam is composed of cobbles from 6-in. diameter down to gravel and sand. At the "drop off," just inside the shore line of the pool, the grading changes to sand, quickly diminishing in size to silt and clay. An analysis of the core material, made by the Bureau of Soils at Washington, showed the following gradation:

Material.	Sieve.	Per Cent.
Fine gravel	2 to 1 mm.	0
Coarse sand	1 to 0.5 mm.	0.4
Medium sand	0.5 to 0.25 mm.	0.3
Fine sand	0.25 to 0.1 mm.	4.6
Very fine sand	0.1 to 0.05 mm.	19.6
Silt	0.05 to 0.005 mm.	52.7
Clay	0.005 to 0 mm.	22.6

Studies are being made, as the dam progresses, of the behavior of the core. It is known that it is becoming stiff at the lower elevations. A 1½-in. diameter pole shoved into the core meets sensible resistance at about 15 ft. The stiffening increases until at 25 or 30 ft. a man's weight will force the pole no farther. It is the intention to test the rate of stiffening in the core by noting the penetration of a 6-in. cast-iron ball. By this means a direct comparison can be had between the cores at the five Conservancy dams. Furthermore, this ball method was in use at the Calaveras Dam for the Spring Valley Water Company in California, and comparisons in penetration can be had with that dam. It is also the intention to insert in the core a number of pressure-recording

devices, developed by the Engineer of Tests, Bureau of Public Roads, Washington, for the purpose of measuring pressures in semi-fluid masses.

At the time the pumping plant was laid out, very little authentic data was available in reference to friction head in dredge pipe. It was thought that, with velocities of 12 ft. per sec., the loss of head would be . oout 4 ft. in 100 ft. In the clayey glacial till, such as is being pumped at Taylorsville, this is approximately true, but in the gritty sands and gravels at Englewood and Germantown, using velocities of 12 ft. per sec. or upward, it is found that the friction head is unexpectedly large, amounting to as much as 8 ft. per 100 ft. Such a condition throws a heavy penalty upon length of discharge line, and accordingly, at Englewood, studies are being made to abandon the present sump late this season and to use, progressively, three other sumps so located as to reduce both static and friction head to the least amount compatible with securing a satisfactory railroad grade from the borrow pit.

A matter entering vitally into the rate of progress of the hydraulic fill is the per cent. of solids in the water handled by the dredge pumps. At times clear water is being pumped; at others as much as 15 or 20 per cent. of solids is carried for short periods. The present average is probably from 6 to 10 per cent. Obviously, the higher the percentage the lower the unit cost, and studies are being made along these lines to find out just what can be handled. In the first place, there is vast room for improvement in the sumps. A sump is now being designed at Englewood from which much is expected. The principle being followed is to drop the material passing the revolving screens into the path of the water flowing to the suction of the pump and to fashion the entrance to the suction into a bellmouth to reduce the loss of head at entrance. But it is one thing to get the material into the pump and another to pass it through a long discharge line without plugging the latter. This feature is engaging the attention of the engineering force, and studies are under way looking to some form of spiral or rifling device which will keep in suspension the solids in the discharge pipe and offset the tendency to settle in the bottom of the pipe.

The monthly progress at Englewood, working two 15-in. dredge pumps, two shifts of ten hours each, has averaged 100 000 cu. yd.

Some minor changes in the screens and sump have lately served to increase that figure so that at present (September 1) each pump is delivering consistently 150 cu. yd. per hour, or a total for the two of 6 000 cu. yd. per day. The total amount placed to date aggregates approximately 650 000 cu. yd.

The hydraulic fill at the other dams of the Conservancy District is following so closely the methods in use at Englewood that only

FIG. 24. TAYLORSVILLE DAM.
Hydraulic Giant operating in Borrow Pit. Also Ground Sluice and Pumping Plant.

the essential differences will be noted. At Germantown the material to be pumped, the location of the borrow pit, and the general arrangement differ in no essential from Englewood. The dredge pump motors are 350 h.p. instead of 500 h.p., but this is on account of the lower head against which they will be called upon to operate.

At Taylorsville, however, the problem at present is somewhat different. As previously stated, this dam requires an excavation of something like a half million cubic yards of glacial till overlying ledge rock for the spillway. This till is high in clay, containing perhaps 50 per cent. The logical thing was to use the excavated

material for the construction of the dam, and the easiest way, considering that a hydraulic-fill dam was to be built, was to pump it into place. Accordingly, a pumping plant consisting of four 6-in. pumps, operated by 75 h.p. motors, was installed at a convenient place near the river. From here water is pumped through 15-in. spiral-riveted pipe to the excavation at 130-lb. pressure, and played upon the face of the pit by means of a hydraulic giant fitted with a 3-in. nozzle. More water is needed to convey the material than to break it down, consequently an 18-in. wood-stave line is run to the top of the face under sufficient pressure only to flow freely. Water for this line is furnished by one 12-in. pump with 150 h.p. direct-connected motor. The high-pressure nozzle handles 6.4 c.f.s., while through the low-pressure pipe 12 c.f.s. are carried. The sluiced material flows by gravity down a rough channel into a sump, from which it is pumped, in a manner similar to that at Englewood, into the dam.

The method of handling the levee ahead of the discharge pipe differs materially at Taylorsville from the dragline scheme described for Englewood. At Taylorsville the pipe, as it comes on to the dam, is separated by a Y-branch into two discharge lines. The end pipe of the line nearest the slope is slotted in the bottom in such a manner that the greater portion of the solids runs out, building up a windrow beneath the pipe. A few laborers handle this material into the levee. As each length of pipe is filled up the discharge is deflected at the Y into the line nearer the center of the dam, and flows through that line until an extra length of pipe has been inserted and the "window" pipe again attached. While this method seems on the face of it to involve less expenditure than that in use at Englewood, it is not applicable for the latter dam, owing to the much greater output there.

But one pump is operating at Taylorsville and working one shift only. The reason for this seeming lack of haste is that they are not ready to begin building the dam in earnest at this time. The hydraulic fill is simply the logical way to handle the earth excavation, and, in turn, the earth excavation is well ahead of the rock excavation, which latter is the key to the spillway construction and river diversion.

The dredge pump at Taylorsville is cast iron. At first, 34-in.

FIG. 25. LOCKINGTON DAM.
Hydraulic Giant working in Borrow Pit.

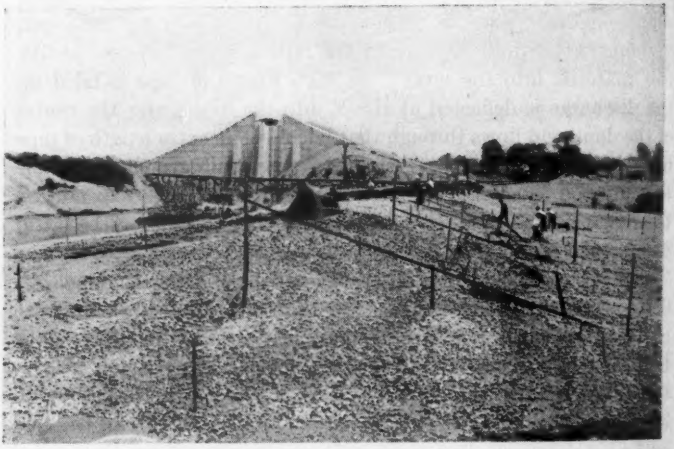


FIG. 26. LOCKINGTON DAM.
Hydraulic Fill; spillway walls in background.

cast-iron impellers were used in this pump, but they handled only from 6 000 to 10 000 cu. yd. These were replaced by 39-in. cast-iron impellers, which handled from 17 000 to 22 000 cu. yd. Manganese steel impellers, 34 in. in diameter, fitted with 36-in. shoes, were then substituted, and have handled to date 60 000 cu. yd. of material without showing undue wear. The original cast-iron pump shell is still in service.

The pumping at Taylorsville has averaged about 120 to 130 cu. yd. per hour with the one pump. To date, approximately 150 000 cu. yd. have been placed. As nearly as can be determined the percentage of solids in the mixture being pumped to the dam averages about 6.

The arrangement of the pumping plant at Lockington is somewhat similar to that at Taylorsville, although for an entirely different reason. There is plenty of suitable earth material well up on the hillside, favorably located for placing into the dam. Furthermore, the old Miami and Erie Canal, a relic of seventy years ago, passes at one end of the dam at a high elevation. This portion of the canal can easily be adapted for a water supply. Taking advantage of these favorable circumstances, a pumping plant, consisting of two 8-in. centrifugal pumps direct-connected to 100 h.p. motors, was located at a high elevation, receiving water from the canal through a flume, and serving a hydraulic giant in the borrow pit at 60-lb. pressure. This giant breaks down the face of the pit and washes the material down a ground sluice into a sump. Here it is picked up by a dredge pump and forced through a 12-in. line into the dam. As yet the hydraulic fill at Lockington is only started, and beyond a successful beginning little has been accomplished.

At the Huffman Dam an extensive scheme of railroad relocation has placed the hydraulic-fill operations farther down on the program than at any of the other dams. It is expected that pumping will begin in the early spring of next year.

The whole subject of hydraulic transportation of earth materials and the adaptation of this method to the building of dams is fraught with the greatest possibilities. We know that under favorable conditions the cost is low. We know also that hydraulic fill, with the right materials, makes the best earth dam obtainable.

But there are many little tricks in the placing of the material that we have yet to learn. We in the Conservancy work are constantly striving for knowledge along these lines, and our efforts are not going unrewarded. Our successes and our failures will at all times be cheerfully contributed to the engineering profession.

TABLE 1.

DIMENSIONS OF DAMS AND APPURTENANCES.

	Germantown Dam.	Englewood Dam.	Lockington Dam.	Taylorsville Dam.	Huffman Dam.
Drainage areas above dam, sq. miles	270	651	255	1 133	671
Maximum height above valley floor	100	110.5	69	67	65
Average elevation bed of river	723	770	876	759	777
Average elevation valley floor	730	782	885	770	785
Elevation of spillway crest	815	876	938	818	835
Elevation of top of dam	830	892.5	954	837	850
Maximum elevation of water surface for a flood like 1913	805	862	936	815	830
Area submerged in a flood like 1913, acres	2 950	6 350	3 600	9 650	7 300
Maximum amount of water stored in a flood like 1913, acre-feet	73 000	209 000	63 000	152 000	124 000
Maximum average depth of water in reservoir in a flood like 1913, feet	24.8	32.9	17.4	15.7	17.1
Length of crest of dam, feet	1 210	*4 716	*6 400	*2 980	*3 340
Thickness of dam at average elevation of valley floor, feet	650	739	410	390	380
Length of outlet conduit, feet	546	709	45	40	40
Number of conduits	2	2	2	4	3
Total sectional area of outlet conduits, square feet	182	217	158	1 116	705
Maximum discharge of conduits in 1913 flood, second-feet	9 340	11 000	8 630	51 300	32 600
Length of spillway crest, feet	55	100	72	132	100
Vertical diameter of conduits (temporary), feet	22 ft. 10 in.	22 ft. 6 in.	.....	.....	.....
Vertical diameter of conduits (permanent), feet	9 ft. 1 in.	10 ft. 5⅜ in.	9 ft. 2 in.	19 ft. 2 in.	16 ft. 4 in.
Maximum width of conduits	13 ft.	13 ft.	9 ft.	15 ft.	15 ft.
Yardage of earth in dams	790 000	3 550 000	1 032 000	1 131 000	1 547 000
Yardage of concrete in dams and appurtenances	20 000	38 000	38 000	47 000	40 000

* Including spillway crest.

PUBLIC CONTROL OVER NEW STREETS IN RELATION TO EXTENSION OF WATER MAINS.

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[*September Convention, 1919.*]

The interesting discussion at the March meeting of this year on the subject of financing the extensions of water mains, especially with reference to the possibility of special assessments on the abutters, suggested to the writer another problem connected with this particular branch of water-works activities. As some of us have reason to know, neither the possession of the money nor satisfactory means for procuring it necessarily secures a proper street to build in. Both suitable conditions and a suitable location may be lacking. Very likely the street lines are not so marked on the ground as to make it possible to properly locate the new pipe line and the new surface fixtures. The few marks on the ground showing the direction and boundaries of the street may be inaccurate and of a very temporary nature, so that, in the absence of proper plans, the street lines are certain soon to become involved in dispute, if they do not disappear altogether.

More often still, the street grade is established only by the surface of the muddy subsoil remaining after the loam has been partly scraped off under the direction of the exploiter who has developed this part of the municipal plan. It is obvious that the utter neglect to fix any kind of a suitable grade on paper and construct to it on the ground is a most important factor in making it impossible to locate the water mains or fixtures at a grade that will insure economy and permanency of construction.

These and similar questions as to the wisdom and practicability of the investment in new water mains have no doubt occurred over and over again in the practice of every man in the operating end of the water-works business. While it is often very difficult to determine whether the public's money ought to be spent in laying water mains in these doubtful street developments, the question

has a larger aspect in that it has to do with the orderly and reasonable development of the whole municipality — the town or city plan. It seems to the writer that the official in charge of the water department can exercise an exceedingly important influence in actually making operative the town or city plan because it is usually he who, by placing water pipe in a new street, first gives public sanction to its layout.

As has been intimated, the most common case that comes up for consideration is that of the land speculator who, if he is of the irresponsible kind, furnishes "a piece of this earth" or a "house site" for an enormous price, but on the instalment plan. He hypnotizes the ignorant public into buying bog holes, or ledges, or what not, only that he may sell as much land as possible, not to the particular advantage either to the purchaser or to the municipality but rather to himself. The writer had occasion once to expostulate with a speculator of this type. After pointing out some of the more obvious defects in his layout and suggesting co-operation on the part of the city authorities for the purpose of securing needed correction, or, if need be, wise and intelligent revision, he was met with the statement that this particular operator "was only a photographer, and knew or cared nothing about plans; he was there to sell land." The net result to the municipality of these sales is that the people build houses and move into the new neighborhood, unthinkingly relying upon the authorities at whatever cost to help them out of a dilemma that is to a great extent of their own making.

As every municipality has suffered more or less in this way, and as very few persons really know what is being done to meet the situation, we believe it is appropriate at this time to spend a few moments in a discussion as to what has been done and what may still be done to remedy the evil.

The initial control of new street development, so far as such control has been exercised, has, in Massachusetts, been delegated to an official body called the Board of Survey, a name that was adopted by the city of Boston in a law passed by the General Court in 1891, Chapter 323, when a Board of Survey was established for that city under the able leadership of ex-Mayor Nathan Matthews. The provisions contained in this law were immediately

put into effect, and, as is well known, streets in a large section of Boston have been laid out on paper by the Board and many miles of streets have been approved under this and subsequent acts.

Briefly stated, the Boston law provided that either through its own initiative or by petition of those developing land, all prospective streets must be given official sanction. Following is a condensed statement of some of the permanent interests of the whole community which are covered by this and later Board-of-Survey laws:

1st. A plan must be permanently filed with the public records sufficiently accurate and complete so that the exact boundaries of the street can be easily reproduced at any time.

2d. This official plan must show a final and reasonable street grade, also capable of reproduction at any time.

3d. Due attention must be given to good connections with existing highways as well as to an intelligent provision for future thoroughfares, all to be secured at a minimum of cost consistent with the conservation of the natural advantages of the entire district for home sites, factory sites, public uses or otherwise, as the case may be.

4th. The development must be such as will provide a good system of sewerage and drainage for the district to be laid out as well as suitable connections with the systems in the contiguous territory.

5th. The new layout must accord with a reasonable development of the water-works system with due regard to cost, accessibility, and circulation.

This last provision appeals to every water-works man, and suggests two questions appropriate to the hour. The first query is as to how such a control can be enforced; in other words, and speaking colloquially, how can teeth be put into such a law; while the second has reference to the application to your own city or town, — Has such an oversight of street development been established there, and, if not, how can its beneficent effects be secured?

The answer to the question as to how private development can be and has been in many instances controlled in Massachusetts

is that, up to within a year or two, the only method of enforcement possible under board-of-survey laws was to refuse public service in any private street not officially passed upon by the proper authorities. In this connection it is almost superfluous to emphasize again the fact before this organization that water pipes are usually among the first, if not the first, public utility installed.

Perhaps the best way to answer this query, and to suggest an answer to the question as to how the beneficent results of this law can be secured in any municipality, is to give a brief history of the board-of-survey legislation.

Attention is first called, however, to a particular provision in the Boston law of 1891 which was expected to furnish a more potent means of enforcement than that of refusal of public-service works in an unauthorized street. Section 9 of that law attempted to prevent building within the boundaries of a street approved by the Board of Survey or at a grade other than one that would accord with the grade shown on the official plans. This particular provision, however, was tried out in the courts and declared unconstitutional in that it took away certain individual rights without adequate compensation. We shall have more to say about this provision later.

As might be expected, the Boston law was soon discovered by several Massachusetts towns and after adaptation to the town form of government, board-of-survey laws were enacted for several of them, notably, Arlington in 1897, Revere in 1900, Watertown in 1900, and Belmont in 1903. The demands for these special laws became so numerous that a general law was passed in 1907 (Chapter 191), providing for a board of survey in any town that, by vote of its inhabitants, chose to accept it. This law is very similar to those already passed, and depends for its enforcement likewise upon the same provision that no water mains or other public works shall be placed in any private street not approved by the Board of Survey.

In 1909 the writer, after consultation and with the help of several legal and engineering friends, secured the passage of a special board-of-survey act for the city of Waltham, also to a great extent adapted from previous laws but modified to conform to the requirements and form of government of the average city.

This law provided that the city engineer should, by the virtue of his office, act as clerk of the board, and while it gave him no judicial authority it made him the executive officer of the board and furnished him an opportunity to accomplish much good at little expense.

This act, which was followed by several special acts for a number of cities in Massachusetts, was finally somewhat amended in 1916 and passed as a general law subject to adoption by any city in the Commonwealth.

As might be expected, these laws, while they have accomplished much good, have not done everything it was hoped for. Recalcitrant real estate sharks have snapped their fingers in the face of boards of survey and gone on with their nefarious work. It has been and is a difficult thing, but, nevertheless, an essential one, to educate the public to an appreciation of the importance of finding out whether a proposed street has been officially approved before buying land abutting on it. As a certain mayor of Philadelphia has said, "The people have not yet learned to think clearly and become sufficiently proud of their right to rule." But we know of one city where a real estate dealer of the type frequently described in this paper actually shook the dust of that place off his shoes when he found that there was a Board of Survey there, and if you will visit a recent development in that same city you will find a big sign conspicuously placed, advertising land for sale, displaying the magic words, — "These streets approved by the Board of Survey."

Certain well-meaning but misguided reformers of the class who see no way either of recognizing well-tried and experienced officials or of backing up or encouraging the men holding office, or, if need be, procuring better ones, but who are always scheming to create a new commission or a new form of government to further their so-called reforms, at one time threatened the successful operation of this law for cities by attempting to wipe out the boards of survey and to put this authority in the hands of planning boards. This would have practically divorced the constituted authorities from the charge of work which is legitimately their particular specialty. The attack was repulsed and the law still stands.

The friends of the Massachusetts board-of-survey laws, on the other hand, have constantly had it in mind to improve them. In 1917, Chapter 185, they were strengthened by adding the provision that any plan of land showing proposed streets or ways in a community where a board of survey has been established must be officially approved by the local board of survey before it can be filed at the registry of deeds. As few banks will take a mortgage nowadays unless suitable plans are filed at the registry of deeds, this law furnishes an important additional check.

Reverting now to the attempts to actually prohibit building within the lines of an approved street, attention is called to a law passed in 1918, Chapter 110. This law applies to towns only, and appears to give to the proper authorities the right to formally establish the lines of board-of-survey streets without compelling their immediate construction. It prohibits new building within the lines of such streets, and provides for the payment of damages. It seems to the writer that its provisions and application are somewhat indefinite, and might involve a town in two damage payments, — one when the board-of-survey street lines were established by the town and another when the time came for constructing the street.

Mayor Peters of Boston attempted this year to secure a control which would prevent unauthorized building in Boston. This bill, House 568, prohibited the sale of land included in a board-of-survey street, and also forbade the erection of a building on any land not abutting on a public or private street or way without the written approval of the Board, and, in case of violation, allowed the city to take possession of land so sold, or of buildings erected without this permission, subject to a proper damage; but betterment assessments could be levied in connection with the establishing of the highway. This bill was adversely reported, owing to a misunderstanding both as to its scope and the necessity for it. It was poorly presented to the committee. The chairman of the committee told the writer recently that if some such provision had been incorporated in a bill which would be applicable to any city in the state where the board-of-survey law had been adopted, he would have been very much interested to secure its passage.

We would suggest that while it is a fact that thus far the government of this country has been wisely built upon the rights of each individual to hold and transmit private property, it would seem that the roads are in a peculiar class. It is certain that just as soon as a street is laid out on paper and lots are sold, abutting upon it, certain public works, especially the water supply, are demanded and the street is started on a course which insures its becoming in time practically the property of the public. Is it not then perfectly reasonable for that public to have some choice as to what kind of property is to come into its possession? It would seem that this peculiarity, ultimate and certain public ownership, puts the new street in a class by itself when it comes to public control over its alignment and grade.

It must not be forgotten, however, that all suggestions as to more public control are more or less speculative at the present time, and we are now working under existing laws, such as they are. It follows, then, that such men as make up this Association, men who know just how things have to be accomplished and what it means to actually put plans into effect, must be depended upon to make the board-of-survey laws a success.

Before concluding this paper mention ought to be made of a phase of the question of extension of water mains which is important above all others. It ought to be noted here parenthetically, even though it may to some extent weaken the force of the argument for board-of-survey streets. The financial question is an important one; permanency and good city planning are likewise of great moment; but we do not need to be reminded that no other question can equal in importance that of the public health. A community cannot afford long to have a disease-producing neighborhood in its midst. No one knows how soon it may become a center of infection for the whole town, and the economic loss in lowered health and morale may be such as to make the cost of almost any physical improvement, or of any extension of the public service, seem a comparatively insignificant item.

Nevertheless, selfish speculators must be controlled, and that they can be controlled to a great extent in the way pointed out in this paper has been demonstrated over and over again; and, after all, the fact that it is likely to become a health question makes

it all the more important that initial control shall be established. Of course, not all real estate operators are irresponsible, and both seller and buyer are usually glad to avail themselves of public control when such control is exercised by a far-sighted and intelligent official who has made a special technical study. We believe, then, that a scheme of control is in the process of making, a control that will ultimately eliminate the uncertainties that confront the water-works officials when they undertake to extend water-works pipe lines into private and unaccepted streets. Can your help be enlisted?

DISCUSSION.

MR. FRANK J. GIFFORD.* I should like to say, for Mr. Brewer's encouragement, that the superintendent of the water works in Dedham and the superintendent of the water works in Plymouth are working along these lines. Plymouth and Dedham both have boards of survey; the power is vested in the selectmen. We could not be selectmen but had ourselves elected to the planning board, so that we could follow those plans along. Perhaps we are dishonest. We hope all water-works superintendents in Massachusetts will follow along those same lines, and then we will accomplish what Mr. Brewer seeks.

MR. DAVID A. HEFFERNAN.† I will say for the town of Milton that we were fortunate enough to fall into line in regard to private ways, and we adopted in 1913 the Board of Survey Act. We had there, of course, a great many demands on private ways, and we had to turn them to one side in regard to the grades for layouts, and so forth.

Now, we adopted this Act in 1913, but gave the abutters on private ways a little leeway. That is, if the layout were approved and plotted before 1913, if the conditions of the grade were such that a fair return could be secured — that is, five per cent. of the outlay — we would consider putting in the pipes, and we had done so up to that time. But since then the speculators have come into different sections of the town and opened up streets, and the

* Superintendent Water Works, Dedham, Mass.
† Superintendent Water Works, Milton, Mass.

conditions were such when the application was made, and we have referred them to the Board of Survey Act.

I think this Act is one of the greatest things for water works or any public utility that has been produced. I hope that every superintendent of every city or town that comes under this Act will have it accepted.

MR. J. M. DIVEN.* I think that this matter should be brought to the attention of the city authorities other than the water companies. To use the expression of the street, it is up to the water-works superintendents who have heard this paper and who will have the opportunity to read it later, to see that it is brought to the attention of the authorities in the cities and towns in which they live; and not only to the authorities, but to the public of the city or town through the local newspapers.

It would be a very good idea if reprints of this paper could be distributed to the members, to be brought to the attention of the newspapers and the city authorities.

MR. T. J. CARMODY.† Mr. President, I am somewhat interested in this matter. I came all the way from Holyoke to be enlightened on just exactly what this gentleman has read here to-day.

The city of Holyoke adopted this bill and then established a 5 to 7 per cent. grade. Plans have to be filed with the city engineer, and the water board gets its instructions through the City Engineering Department to lay the mains. We have laid mains that cover now about twenty feet of the street surface.

Holyoke works under a charter — possibly there is no other city works under charter. It is owned by the city but absolutely in the control of three commissioners. In looking around I suspect that all are paid that come here. Now, the three commissioners in Holyoke are unpaid. They have absolute control of the revenues of the department. They collect the money, they disburse it, they invest the funds of the department.

The problem which we have been up against is this: The land sharks came to Holyoke and opened up great portions of undeveloped land, ran a plow through and called it a street, sold lots upon those so-called streets, and asked the Water De-

* Superintendent Water Works, Troy, N. Y.
† Water Commissioner, Holyoke, Mass.

partment to lay mains, which they did in a good many cases. On account of the high cost of everything, the department now needs additional funds, so that the question arose how to get additional funds; whether or not we were going to raise the water rates, which are very low at present, or devise some other scheme. So the commissioners passed a vote that we charge for any new extension of main a dollar a running foot. Now, we thought that the thing was quite perfect, but we found that it was not.

In laying an extension, one man had a lot 60 ft. long, another a lot 75 ft. frontage, another 80 ft., and a fourth, 100. We found the man that wanted it extended to his lot, not to go beyond that lot, and the entrance was to the center of his house, which of course usually was in the center of the lot. He said, " Why, you haven't put in 75 ft. of main; you have only put in 30 or 40 ft.; I am not going to pay for the 75 ft. which you have not put in." Of course the main stopped where the entrance was; there was nothing built beyond it. So that we ran up against that snag, and came here to-day thinking that we would get a little enlightenment from you.

Now we have solved the problem. We found that we extended mains into streets where there was a house built and nothing had been built upon that street for a number of years. The main is already laid in that street. The question came before us, How are we going to charge the builder of a house upon that street now that the main is already in? The superintendent and our engineer differ upon that point. We have referred that matter to the board, as to whether or not we ought to have a fixed sum, requiring every person making application for a service to pay some fixed sum, and allowing the dollar a foot to stand. They presented a report jointly signed, but differed on the details. The engineer says that we ought not to make the charge where the main is already in the street; the superintendent says that we ought to. And they present tables showing that we would get less revenue charging a dollar a foot than we would in making a fixed sum. That is, that we would have more service applications on undeveloped land where mains already exist that would bring in revenue of from $2 000 to $4 000; whereas if we applied the dollar-a-foot plan we would only get $200 or $300.

The estimated value is about $2 000 000, and the net debt is only $250 000. We are selling water low, — $6.40, or something around that, for a family. The meter rate is 5.1 cents a thousand gallons. Very little of the water is metered. We do not wish to advance the rates, but want to get after the land sharks. The people who purchase those lots are trying now to compel the land sharks to pay the city. We have got to do something, but do not know what, owing to the question of the difference between our engineer and the superintendent.

If the gentleman has looked into that matter at all I should like to ask him if he can give us any enlightenment upon that.

MR. BREWER. I do not think I can throw any light on that matter just now, Mr. President.

MR. W. A. MACKENZIE.* I think both of these questions are very important. In Wallingford we make no extension unless it pays eight per cent. on the investment. Also, there is to be no main extension unless the developers of the property properly grade the streets previous to the pipe being laid. The department had to adopt this rule as the municipal authorities — although this is a municipal plant — let the land developers come in and begin to sell lots on these streets that they simply blocked out without paying any attention to the contour of the ground, in regard to the levels of sewers or later developments; and it has become so now that if the question comes up in regard to these streets, the municipal authorities will ask, " Have you got a water pipe in these streets? " and we say, " Yes," but it has got to be moved if that street is accepted. So that the department itself had to bring about the ruling to prevent all of these past troubles of being obliged to relay mains and to get mains into streets where the revenue would not be sufficient to warrant an extension. It has grown to be a very important question. Only recently we started in on new grades on a certain street and the house development and construction, the sidewalks and curbs, had followed the original contours of the ground regardless of this development. And, in order to get things straightened out, these blocks had to be lowered, and the municipality has now to pay damages of over $3 000. It is something we have perhaps

* Superintendent Water Works and City Engineer, Wallingford, Conn.

some responsibility for, in not compelling the original developers, some fifteen or twenty years ago, to follow some established grade.

It seems to me as though this is a very important question at present, to save the municipalities large expenditures in damages in future years, and also to prevent land sharks from opening up new tracts and simply plotting them out to their own greatest advantage in selling the lots. I think that the municipality should ask the engineers or developers to conform somewhat to the contours so as to prevent undue future development for the laying of sewers and grading of streets. In the past they have in many cases simply let them block it out regardless of the hills or hollows which may exist in the development. The development would be along better lines and present a better appearance, the street would make better building lots, if they paid a little more attention in the development to the blocking out of the lots so as to follow the contour of the ground somewhat.

Mr. George A. Stacy.* I think this paper touches a vital point of almost every working engineer in every growing town or city. When we first started, with the rush the work called for, the improvement of the streets was not given particular attention. The street was laid out, an estimate of cost was asked for, and the price of construction based on that.

Now, we found that new streets were laid out and the grade established by the men who sold the land for house lots. The width of the street was not definitely stated, or was not controlled by the city, and the consequence was that when an estimate was called for we had to make it as we found conditions, and then after awhile, when there was some building there, they wanted the street built. It was not a very good street that the promoter built, as a general thing. You would be hub deep in mud in the spring, and it was filled with old rubbish. When the city took it up, the first thing we had to do was to set the grade, and we found we had buried the pipe 10 to 12 ft. in some places and left it bare in others. So that the time came when we passed ordinances that no water pipes should be laid in private ways until the grade had been established by the city engineers and the grading and filling paid for by the outsiders. We thought we had it all right —

* Superintendent Water Works, Marlboro, Mass.

and it looked that way. But here is a man who laid out a street, and the city engineer established the grade; they asked us then to make an estimate for laying the pipe. They complied with the requirements creating the revenue, and then some of them wanted to do this cutting and filling themselves, and asked the superintendent if he would not put in the pipe and trust to their honesty to do the grading. If the cut was not large the request was granted, and the pipe laid. The result was that they found it pretty hard work to get the pipe in in cold weather so as to protect it from the frost.

Another thing has now come up. One of our large manufacturers, an owner of a large lot of real estate, opens up a new tract of land called " Chestnut Hill." He laid out and built fair streets with proper width, and asked for the water pipes to be laid in those streets. He wanted to build houses there. The scheme was, instead of starting at the commencement of the street, he put one house about in the middle, and built another one at the end. His guaranty was 10 per cent. for ten years on the total estimated cost for laying the pipe. Well, as he was a very progressive man and had built up a large section of the city through his business enterprise, the city felt bound to go ahead with this, and as he laid out a large tract there and went to considerable expense the city laid the pipe, which probably would not pay more than one per cent. from the amount of buildings that were there at that time. That was all very well if this man had lived, and we could not tell that he was going to die before this thing had developed. The consequence was that this large tract of land, with a mile of pipe or more laid in it, only had about fifteen or twenty houses on it. Instead of collecting a revenue of 10 per cent. for ten years, we have to fall back on what we can get out of the people that live there. It was all laid out into house lots. There is a problem which it is pretty hard to solve. Here was a man who had done so much for the city, he wanted this work done and was willing to do the reasonable thing, as he thought, of guaranteeing 10 per cent. for ten years, by which time he thought the place would be all built up.

Our experience before that had been that this arrangement had proved satisfactory on practically all our streets, but those de-

velopments were not as extensive as this one. The revenue required was wiped out before the time elapsed, so that we got more than the required revenue from the regular returns from services.

But then in came the land sharks and touched our city a little bit. We had one property where we laid out the streets. They wanted to know how soon we could get a water pipe in. I looked at it and said about three months if I had plenty of steam drills to blow out this rock. It started off with a good solid ledge right from the main street. Some people were foolish enough to buy house lots on that land. That is the condition to-day. We have recently had a development start there. It is hard work, it seems, to make the public see that it takes time and money to put water pipe and sewers through, and they expect when they build the house that you are going to rush in and give them the water, no matter what the revenue is or what the cost is going to be.

The result has been that we have a large amount of pipe that is paying very little money, and are still working under this same rule.

Now, the sewer was the same way. When the legislature consolidated the sewer and the water departments, I introduced an order to have the same rule apply to the sewer as applied to the water pipe, — that none should be laid in a private way until the grade was established by the city engineer.

To show how little attention the city government sometimes pays to the recommendations of the water superintendent, — although they are willing to pay a first-class salary, they are not willing to listen to good advice, — there has never been any action taken, and quite recently in a sewer extension we were obliged to build, in order to get this sewer in, at additional expense which should properly be applied to the man promoting the scheme.

So we are all up against this same problem. It is hard work to devise a scheme, because when you say you want the city to take hold of this matter and make the ruling, which is evidently for the benefit of the whole community in the long run, they want to do it the easiest way and let the poor city stand the brunt of it

afterwards and do the work twice. I think most of us have been up against this same problem of seeing the unnecessary work done, when, if proper rules were put in effect, the promoters of this property would educate the public in buying the land to see that a provision was made that the water and sewer should be introduced, and we would soon be over this trouble. It is a hard thing to do. When a man buys, or twenty-five or thirty people buy house lots scattered around a proposed extension, and invest their money there to make homes for themselves, and then ask you for the water supply that won't probably pay more than two or three per cent. on the cost, it seems hard for the city to do it, and it seems hard to refuse these people who, insanely or ignorantly, have invested their money, their hard-earned money, in establishing homes for themselves, and then want the utilities, the necessities, that they never thought of before. That is a pretty hard problem, and it seems pretty hard work to impress upon the public the necessity of making some provision for educating the people up to demand these necessities. It is like the man going to work and building his cellar without making any allowance for the entry of sewer or water pipes, gas, and so on, and then later on it is necessary to tear down his wall. That does not pertain to this question at all, but it shows how careless the people are, who buy these properties, about other things connected with it. It seems hard to compel them to pay anything extra for it, but at the same time they have their money invested there and they can't live without the water, and the question is, What are you going to do about it? The superintendent is placed between the two millstones. He feels in one way that the people are entitled to the service, while his interest on the other side compels him to say it should not be done unless a proper amount of money will be received to pay a reasonable return upon the amount paid for extending the main and the sewer.

It is a very vital question for some of us; it touches the growth of the city, the home-builder, and the citizens in general.

MR. M. N. BAKER.* We should bear in mind in speaking of this subject that 25 to 40 per cent. of the area of our cities is occupied by streets and other public places; that in the past the

* Associate Editor, *Engineering News Record.*

real estate developer for his own selfish ends, as has been so well pointed out in the paper, controlled the layout of streets to a very large extent, almost wholly in many cities, instead of the matter being under the control of the city for the benefit of the people for all time. The interest of the real estate operator is momentary compared with the scores or hundreds of years that the people must suffer for the mistakes that are made.

This subject that has been presented in this paper, it seems to me, is really only one element in the broader subject of city planning as a whole. The people of our cities are interested not merely in street grades and the layouts of individual streets; they are interested in the entire street plan of the city, and in order to have these things right we must have bodies in control of city planning which will take all of these things into account.

Now, it appears from the paper and from what information I have from other sources that in Massachusetts the boards of survey, having control of just a portion of the elements that enter into city planning, got a foothold before we knew much about city planning in this country. And it also appears, although it is not brought out in the paper, that the city planning boards, which I understand are compulsory in all cities in Massachusetts and may be adopted by towns of 10 000 population and upwards, have really very little more than advisory powers. These boards of survey seem to have considerably more power, — some real authority.

Now, whether it be the board of survey or whether it be the planning commission, the whole matter, all the elements that enter into city development, should be vested in a well constituted board which shall take all into account. In the municipal program framed by the National Municipal League — which is essentially a model city charter with supporting documents — there is a very brief provision for the city planning board, which I had the opportunity to draft, and if I may be allowed to do so under the circumstances I would commend that section of the model city charter to those who are interested in this subject.

I would say, further, that these topics which have been up for consideration, as brought up in the paper and by a part of this discussion, — all of them that relate to city planning and that

relate to this very troublesome question of controlling streets and preventing real estate men from locating houses, as they will, right in the street that has been laid out, have been discussed at length from year to year in the city planning conferences which have been held for a number of years past. There is a vast amount of material bearing upon this subject to be found in the annual reports of those city planning conferences.

MR. BEEKMAN C. LITTLE.* This paper has been very valuable, as well as the discussion which has followed it. But I think I may possibly throw a monkey-wrench into the machinery. It seems to be that a false note has been struck, at any rate to some slight extent, in the antagonism to the real estate man.

I think our city board of survey or city planning commission has a much better chance of getting along with the real estate man, instead of calling him a crook and a land shark, by asking his help or at least pretending to ask it. The real estate profession is an honorable profession; it is legally authorized; it is earning a living; the men in it are not all crooks and they are not all land sharks, and if it was not for the real estate man I believe our cities would not progress nearly as fast or as well as they do. I do not believe that Rochester has better real estate men than any place else, but they certainly are a good lot of men, — a great many of them, — and they are not any worse, certainly, than the average lot of men in other lines of business. I think you will get a great deal of help from the real estate men, and that they will be very glad of your help.

I think in the paper it was suggested that advertising was a good thing for the real estate man, and they are very quick to take it up. In Rochester we not only ask them to submit their plans to us before they are approved, but we go further than that, perhaps, and help them plan out their layout. It seems to me that we should not go against them entirely.

MR. CALEB M. SAVILLE.† I think this is a most interesting subject. It is apparently vital just at the present time; nearly everybody is interested in it. And I should like to make a motion that a committee be designated by the President to consider,

* Superintendent Water Works, Rochester, N. Y.
† Chief Engineer, Water Department, Hartford, Conn.

collect data, and report with recommendations on the matter of assessments of the cost of main pipe extensions, and the relation of new street layout in connection therewith, this report to be submitted not later than the next annual convention.

(The motion was seconded.)

MR. FRANCIS F. LONGLEY.* I guess the members of the Association know well enough I am not a real estate man, but I have something I want to say in line with what the gentleman from Rochester has just said.

I have a feeling that a great deal can come from coöperation rather than from indiscriminate condemnation of the real estate men. There is no doubt in the world but that the real estate men in the end do a great deal in the development of cities. But I have in mind another class of technical assistants that can also be brought into this campaign. More or less has been said this morning in the way of criticism of both the seller of land and the builder of the house, placing some of the responsibility and blame for illogical developments on both.

Where does the architect come in on this? Oftentimes the architect is utterly neglectful of the trouble that he is getting his client into. I won't say that he is always neglectful, because a great number of architects are very considerate and careful in their arrangements for water pipes and drainage; but I know from experience that it sometimes happens, or it often happens, that the architect could save trouble for his client and save trouble and expense for the city if he would do what he should do as a technical and professional man in this direction.

Effective action along any line of this sort can more often be secured by coöperation rather than by condemnation, and it seems to me that in proposing a motion of this sort, such as Mr. Saville has proposed, for the consideration of this question, it would be well to include therein a proposal for the consideration also of coöperation that might be secured both on the part of the real estate men and of the architectural profession, in order to well round out the question.

MR. FRANK J. GIFFORD. I think that the architects are not considered in these developments which are the chief offenders.

* Consulting Engineer, New York.

I find in most cases of land development there are no architects employed. The man who buys the lot builds the house, or the contractor builds a bunch of houses, and the chief offenders are not on the tracts where architects are employed, but the houses are built on cheap tracts of land and the owners engage no architects.

MR. LONGLEY. I still believe that motion could be made more comprehensive.

MR. J. F. SULLIVAN.* Inasmuch as this is a very interesting subject and the discussion has not been completed on it, I move that this matter of the resolution be laid on the table until the discussion of Mr. Brewer's paper is completed.

(The motion was seconded and carried.)

PRESIDENT KILLAM. The following motion is on the table: That a committee be appointed by the President to consider, collect data, and report with recommendations on the matter of assessment of the cost of making pipe extensions, and the relation of new street layouts in connection therewith, this report to be submitted not later than the next annual meeting.

On motion of Mr. S. H. MacKenzie, duly seconded, the motion was taken from the table for discussion.

MR. S. H. MACKENZIE. I agree that this is a very important matter, one which we have a great deal of difficulty with. We have had as much difficulty in regard to streets which are at present open and are considered public highways. I think if that had had proper consideration a great deal of expense and trouble which a good many of the water-works departments had during that very cold winter would have been overcome. Streets in which pipes were laid on which no grades had been established were later cut down and the pipes left at a very shallow depth. A new superintendent coming along, not knowing what had been done, would not have the pipes lowered. If proper grades had been previously adopted and the pipes laid to that, the expense of lowering the pipes would have been done away with.

Our department is run in practically the same way as the department in Holyoke, and when we are called upon to lay a pipe in a certain street and find that that has not been properly

* Superintendent Chicopee Water Department, Chicopee, Mass.

graded, we, at the present time, are unable to get a grade from our authorities. Although a great many of our streets have been used for years, they have neither a street line nor grade. There are two places that I have in mind. In a great many places there are no fences and no maps on file of the streets at all. It is difficult to know where to lay the pipe in regard to lines and grade.

Especially in the town of Southington we are up against it in getting the grades. I happen to be the engineer who makes the maps and grades, and when I ask for the grade it looks as if I was asking for a job. So that it makes it difficult for us to get what we should have. I have even gone so far as to recommend that the water department and the gas company apply to the town and signify their willingness to pay a portion of the expense if the town authorities will only establish lines and grades on all the streets, so that we can know where to lay our pipes. If that were taken up and a proper state law put through, we could then immediately tell those who make application for water that we cannot lay our pipes, according to law, until the proper grades and lines have been established, and it would do away with the petty jealousy which sometimes crops up in small places.

The law at the present time in regard to new streets is fairly good if the authorities would follow it out. Anybody who opens a new street is required to have the same approved and accepted by either the selectmen or the city authorities. But they are not always careful and do not always handle the matters as they ought to. For instance, last week I had an inquiry from a certain party in regard to a street, and I asked him if he had had it accepted. "Why," he said, "I have been to the selectmen and they asked me if the ground was level, and I told them, 'Yes,' and they said it was all right." I said, "Have you got a map to show where it is?" "Why, no," he said; "it is on that hill up there." Well, that is about all that he thought he had to do, and it was a wonder that he did not get the street accepted by simply filing a piece of paper. But it has so turned out that before it will be accepted he has got to have a proper profile made.

So that I would like to see incorporated in that motion something in regard to old or present streets, — something after the pattern of the Massachusetts law.

PRESIDENT KILLAM. If you will pardon me, I think that could be very properly considered under this motion that is pending. I should think that the members of the committee would take up all phases of the question without amending the motion.

MR. WALTER T. SCHWABE.* I should like to see the word "assessment" in the resolution changed. There are many privately owned companies in the Association, and in that case the word "assessment" does not apply. Ordinarily they do not have a great deal of difficulty in the method of making extensions for real estate projects, as they have to build up the community, and the future of the water company depends upon the growth of the community.

The gentleman from Holyoke the other day was in a quandary as to how to get sufficient capital to make the required extensions. Of course a guaranty from the promoter gets you nothing except a lot of trouble, but that can be handled by obliging the real estate promoter to pay for the extension and then returning the money to him as he sells the lots and the houses are built. Any works will know what they are operating for, how much they need for interest on the investment, depreciation, and taxes, and they can determine whether they want eight, ten, or twelve per cent. returns on the investment. They will know how much money they can spend for each house. If they can stand $100 for each house and the man wants an extension costing $500, he can pay $400 for that extension and have it returned to him at the rate of $100 for each house that is in the future put up. We do not have any difficulty in getting along with real estate promoters on that basis, as they realize that the mains are put in there to help them sell the land and the houses. The money is returned to the promoter as the building gets on.

It would be well if we had a standard method on which extensions were made, but I think that the word "assessment" in this resolution should be changed so as to include private companies.

PRESIDENT KILLAM. Are you ready for the question? Perhaps I had better read this again:

"That a committee be appointed by the President to consider,

* President and General Manager, Water Company, Thompsonville, Conn.

collect data, and report with recommendations on the matter of assessment of the cost of main pipe extensions, and the relation of new street layouts in connection therewith, this report to be submitted not later than the next annual convention."

(The motion was carried.)

MR. BREWER (*by letter*). The writer desires to thank those who participated in the discussion. He is entirely in accord with the suggestions of Mr. Baker, and believes that the provisions for city planning drafted by him in connection with the model city charter proposed by the National Municipal League show great care in their preparation and a lively appreciation of all the elements involved. The writer of the paper believes, however, that emphasis should be placed on the effective help that practical men in the operating end of the local government can accomplish in solving the problems under consideration. That is why the paper was written.

He does not believe that a city planning board, as it is constituted in most of the Massachusetts towns and cities, under existing laws, except in cases where it has an executive member who has an appropriation and a force of surveyors at his disposal and who will put plenty of his own time and ability into the work, will ever be able to accomplish much in the way of controlling street development. The executive officer in the smaller towns and cities is usually the town or city engineer who ought to have the requisite ability to grasp the problems involved and should know what he ought rightfully to have, and keep after it tactfully and persistently until he gets it. If he is the superintendent of water works, or can get the help of the superintendent of water works, it will go a long way toward success.

The idea of coöperation among all the persons representing the various interests involved, as expressed in the discussion, is more than an idea, it is an ideal, and one which must be continually before us.

SWIMMING POOL MANAGEMENT.

BY WILLIAM P. MASON, PROFESSOR OF CHEMISTRY, RENSSELAER POLYTECHNIC INSTITUTE, TROY, N. Y.

[*September 30, 1919.*]

Of course a swimming pool should be constructed in a satisfactory manner from an engineering standpoint, and it is especially desirable that the means of getting the water out of the pool should be carefully looked into. Several pools that I have had more or less to do with have their outlets in the side. That is a very serious error. If there be any deposited matter in the pool that is to be gotten rid of it is practically impossible to draw such sediment through any side orifice without nearly emptying the pool. If the orifice be in the floor, then the material can be pushed on top of the outlet grating and a very few turns of the valve handle in the pipe leading to the sewer will dispose of the sediment without difficulty and with small loss of water. With a pool the size of ours at Troy, containing 100 000 gals., unnecessary loss of water quickly runs into money and attracts the attention of people who have to pay for it.

I have noticed that the side gutters are sometimes poorly designed. If they extend too far from the wall it is a very serious inconvenience; on the other hand, if they are covered by the overhang the swimmer cannot easily spit into them unless he is a dead shot, and in his efforts to do so he often misses entirely and the sputum gets into the pool, where it proves a most disgusting thing for a bather to swim up against.

"Fill and draw" pools are usually filled and emptied about once a week. This type is getting somewhat scarce, and water must be pretty cheap in order to allow of such a form of operation. More commonly the water is continually circulated as at the Rensselaer Polytechnic, is subjected to some system of improvement, and is replaced after long, stated intervals. At Rensselaer we retain

the same water for a year, making the change in August. That time is selected because the students are then away and we can run out the old water, look things over, and refill with less inconvenience. Throughout the year the same water is continually circulated by the pumps through the filters, of which we have four, each 4 ft. in diameter. Our rule is to chlorinate once a week with " chloride of lime." Where the same water passes constantly through filters using alum it is necessary to keep watch of the alkalinity and restore it at times with soda ash.

What is to be done in the way of protecting the pool by rules? It is easier to make than to enforce them, and at times some failures will occur, but on the whole they are not troublesome. So far as disease transmission is concerned, people who are suffering from anything very serious are not likely to ask admission to the pool, and if they do ask admission it is the watcher's business to keep them out. I believe that there is less trouble in the matter of damaging the pool from specific diseases than people imagine, due very largely to the fact that people who are suffering therefrom do not care about entering the bath, and certainly they do not care to be caught doing so. We do not ask that a man with a slight cold shall refrain from bathing. In some places they do ask that, but it is carrying the protection of the water pretty far. I have no doubt that a man with a mild cold can easily get by without being detected and get to the pool if he wants to go.

At what temperature is it best to keep the water? At Rensselaer we keep the pool at 76°, except on the occasion of a swimming match of some kind, and then we run it down to 72 merely to put a little " pep " into the men who are performing. Under ordinary conditions if one is going in simply for the pleasure of having a dip, or for learning how to swim, anything short of 74 or 76 makes it a rather strenuous undertaking. In the summer time a swim in the open is quite different, and one can stand cold water then very well, but with a pool under cover in the winter time, unless the water is up in the 70's a bath feels uncomfortably chilly. Of course a Turkish bath is a different proposition, — a cool pool is needed under those circumstances in order to start a reaction from the very high temperature to which the bather has been exposed.

High color or turbidity is unsightly, and masks such undesirable floating material as sputum, but beyond that either may be absolutely dangerous. I have in mind what happened at one of our large institutions not many years ago. The pool was very turbid, and on draining it a man who had been missing for some days was found at the bottom. Unless the bottom of a pool can be seen it is better not to use it. A prominent girls' school has recently closed its pool on account of the turbid character of the water. While it was still in use, whenever a group of girls went in the teacher had to keep watch all the time to see if somebody was missing. A turbid pool is very dangerous and should not be tolerated. A color or turbidity small enough to be possibly unobjectionable in a drinking glass might be sufficient to prevent the bottom of a pool being seen through a depth of 8 or 9 ft. Partly in this connection, it may be permitted to add, at one of our universities a fatality was occasioned by a student diving into an empty pool at night. Such an accident can of course be guarded against by suitable rules controlling admission.

To remove the sediment which collects at the bottom of the pool we use a sweep at Rensselaer, and push everything that settles on to the top of the outlet grating, whence it is flushed to the sewer by suddenly opening the valve. As I have already said, the grating must be on the bottom rather than on the side, to allow this to be done.

In pools used by women bathing suits are worn, usually colored ones, and the amount of fiber that comes off is vastly more than one would think, and it is most unsightly. I saw a device not very long since in Boston, designed to remove such material. It is best described as a modified carpet sweeper of the suction type, entirely similar to what is ordinarily used for cleaning floor rugs. The handle is about $1\frac{1}{4}$ in. in diameter, and of course it is hollow, and is attached to a suction motor by a hose. There is a brush at the bottom end, about 18 in. long and 6 or 8 in. wide, filled with stiff bristles set along a slot. Upon applying suction, the material goes out through the handle and is discharged into the side gutter.

Although chlorination and filtration are the usual means employed for keeping the pool water in proper condition, there are two other ways of securing water improvement — ultra-violet

light and ozone — which have been somewhat recently introduced. The University of Illinois formerly used chlorination, but they are now using ultra-violet light, and they speak well of it. As a device it is certainly very attractive in appearance. You may remember that the Athletic Club at 59th Street and Sixth Avenue, New York City, uses it successfully, although with what charge for upkeep I cannot say. The Board of Health of New York City has pretty thoroughly threshed out the question of ozone, and has reported favorably on it. The amount of money which is quoted in the Board of Health report is small enough, but the upkeep of an ozone plant is usually considerable. It is a fragile thing. And so is the ultra-violet light outfit a fragile thing. We have one in Troy used for other purposes, and we have found it to be pretty fragile in our experience.

At Rensselaer we attempt to keep our alum dose about one grain per gallon, but of course we do not hope to strike that amount accurately as we employ self-feeders. It is not as though we had a large plant where we could run in a well-controlled alum solution.

So far as chlorination is concerned, we use a very homely, but, we think, an efficient method of application; ordinary bleaching powder is mixed up with water into a cream and distributed directly by hand at the shallow end of the pool. In dose we use " bleach " enough to correspond to .6 of a part per million of chlorine, which is the amount legally adopted in California. At Yale they use .3; Northwestern, .6, the same as we do; and in some other instances the dose is as high as 1 part per million.

You probably know that there is an immense amount of objection on the part of some bathers to the dosing of a pool. We have had complaint, time after time, and it is usually based upon imagination. A bather cannot detect the presence of .6 of a part of chlorine per million. In practical tests we found that there was a suggestion of smell at $1\frac{1}{2}$ parts chlorine per million, but no taste and no action on the eyes whatever. At $2\frac{1}{2}$ parts per million of chlorine there was a faint smell, but there was no taste and there was no action on the eyes. When we ran up to 50 parts per million, of course we got a strong taste and we also got a strong smell, but did not notice any action on the eyes. The bathers have complained of dosing when no dose had been given. I

remember that, years ago, when we were about to turn on the alum at the new filter plant at Elmira the people tasted the alum four days before we put it in.

With reference to establishing a legal standard for the water of swimming pools, I know of only two states that have made the attempt, California and Florida. California has a pretty liberal standard. They attempt to keep the total count of bacteria below 1 000. At Rensselaer we do better than that. It may be rather more good luck than good management, but we have been running on an average of about 250.

So far as the presence of *coli* is concerned, we rarely get *coli*, as our .6 of a part per million of chlorine every week seems to control their growth. California allows one bacillus *coli communis* per cubic centimeter.

The preliminary showers should not be too cold and the soap used should be liquid. Many people dread a cold shower although they do not object to a cool plunge, consequently unless arrangements are made to take the chill off the shower water the actual washing accomplished by it will be rather sketchy.

Pools that are built in the open without protection from direct sunlight will probably be troubled with growths of algæ, especially if they be filled with ground water. Copper sulphate is the natural remedy in such a case, and the amount required, which is very minute, is best determined by trial. Considerable stress is sometimes laid upon the advantages of direct sunlight in those unusual cases of such indoor pools as possess it, but the gain is offset, at least in part, by liability to algæ growths. In such instances copper sulphate is again useful, but the need for complicated apparatus to administer the dose is unnecessary. Plants supplied with such dosing outfits seldom or never employ them.

Referring again to outdoor pools, it is unfortunate that some cities, even large ones, are not sufficiently careful to select suitable sites for their public baths. When a city goes so far as to fence off and equip some portion of a river or bay, setting aside the same as a public bathing place, the bathers have a right to assume that the site has been selected with care and that the water is hygienically safe, but sometimes the assumption is distinctly risky. In one instance a great metropolitan sewer emptied on the upstream

side of a public bath (now closed) and so near that when the sewage was colored by a red dye the bathers were startled by the bloodlike tint of the bath water.

It is vain to hope that high bacterial counts and the presence of "gas formers" can always be avoided. The human animal is not quite clean enough to insure that, but nevertheless it is entirely feasible so to run a public swimming pool as to keep its appearance attractive and its use within what may be termed "proper and reasonable risk."

Discussion.

Mr. Arthur L. Crane. Unfortunately, I am connected with the filtration business, but I speak as a member of the Association for Promoting Hygiene and Public Bathing.

I have made an investigation of about 500 pools, and the results of my investigation have been such that I should like to endorse all that Professor Mason has said, if a layman can endorse so eminent an authority.

In the matter of sterilization, I should like to make this point clear, — that as the result of my observation, and notwithstanding the fact that we, in company with all the filtration companies, supply a device for the feeding of hypochlorite of lime to the pool in connection with a filter on a circulating or so-called refiltration system, I have found that the results obtained by the primitive method described by Professor Mason of direct application are entirely superior to any method of feeding hypochlorite of lime to the water in its course of circulation, or any other method of sterilization. Ultra-violet rays, chlorine gas, or the hypochlorite of lime feeding device, are designed only to feed a given amount of sterilizing property to the water in its passage through the pipe. Therefore the sterilization takes place only in the small volume of water contained in the pipe or receptacle to which the hypochlorite of lime, the chlorine gas, or the ultra-violet rays are applied.

We therefore have a portion of a pipe, perhaps 2-in. pipe or 3-in. pipe, to which is applied the requisite dose of hypochlorite of lime or the requisite dose of chlorine gas, or its passage through the ultra-violet ray apparatus, where it receives the rays of light which

electrocute the germs which are for the moment in that 2-ft. run of water. That water is sterilized. It passes on into the pool, which is contaminated and impure. It was not impure when it was first filtered and passed into the pool, but since then the bodies of the bathers have added certain contamination. Then, as the impure water comes back into the sterilizing means, whatever it may be, whether it is my hypo device or the chlorine gas or the ultra-violet rays, the particular body of water passing through that machine is sterilized for the moment. But that sterilized quantity of water, usually in a 2- or 3-in. pipe, 2, 3, or 4 ft. long, passes on to the contaminated pool. It is therefore only a diluting process. You have a pool of 100 000 gal.; you have at the moment only a few gallons of water contained in the portion of the pipe or the contrivance to which the sterilization is applied, and that sterile water is introduced into the unsterile pool and is supposed to purify it. It only dilutes it.

I submit to you that the primitive method described by Dr. Mason is, as a result of my careful investigation of over 500 pools, the real thing. If you desire to purify the body of water, apply the required amount of hypochlorite of lime directly into the pool, and for a time at least you have approximately sterile water.

WATER SUPPLIES FOR THE AMERICAN EXPEDITIONARY FORCES.

BY COL. FRANCIS F. LONGLEY, CONSULTING ENGINEER, NEW YORK, N. Y.

[*October 1, 1919.*]

Mr. President and Gentlemen of the Association, — I have been home from Europe only about a month or six weeks, and am very glad indeed to meet my friends of the Association and tell them a little bit about the water-supply work "over there." I think that the work has been advertised very little, and I consider it a privilege to be able to tell you something about it.

I went over in August, 1917, at a time when the affairs of the American Expeditionary Forces were quite in their infancy, and when there was practically no work demanded in water-supply lines. I had been over there only a few days, though, when things began to develop, with demands for the increase or improvement of water supplies at ports, camps, hospitals, etc. For the first five or six months the work of the water-supply organization was confined entirely to work in the S.O.S., as it was afterwards called, or, in better-known terms, along the lines of communications.

The first work that was done was in connection with the improvement of water supply at some of the base ports, — Bordeaux and St. Nazaire especially, — and later some of the other ports, and numerous camps and hospital centers, and other centers of American activities. The work at the front — that is, the work for the combatant troops — did not start, of course, until the American forces were about to take over independent responsibility for a portion of the front, and that commenced in the early months of 1918.

During the fall of 1917 a number of the officers who had been sent over for water-supply work visited from time to time with the French and the British armies, especially at times when prepa-

ration was on for an offensive, in order that we might have the opportunity of observing what the French and the British were doing in preparation for water-supply work. And I might say that both the French and British authorities were extremely cordial and helpful, and gave us every facility for learning as much as we could and getting every possible benefit from their experience. Their experience had been a grilling one, and the help that we got in the beginning of our own problem was very substantial.

I feel that the matter of most general interest to the members of the Association is not so much the details of what was done in the field, because that, after all, was largely crude engineering; but, rather, the policies and the arguments relating to the policies, that were established for the prosecution of the water-supply work in France. The conditions, of course, were absolutely new; the whole problem had to be started and the organization and procedure built from the ground up.

Conditions in Former Wars.

One of the developments of the European War of 1915–18 has been the formation in the French and British armies of a branch of the Engineer Department known as the Water-Supply Service. A special organization for this purpose had not been known in any other war. In former wars, when armies were much smaller and more mobile and less constant in position, there was neither time nor serious occasion for the establishment of special water supplies for the troops. The conditions of this war, however, have been distinctly different from any former war, and the need for a provision for water supplies has arisen because of the relative immobility of the front, the concentrations of troops, and the higher standards in comfort for the troops that we are disposed to try to attain.

For its water, an army formerly lived upon the country. If the region was rich in water, all went well. If, on the contrary, the country was dry, the soldiers shared the lot of the inhabitants. If anybody gave any special thought to the question of water supply for the troops, it was the staff of the various units. Regions

without water were avoided as far as possible. Locations for camps and lines of march were selected where springs or good streams were convenient. Artillery and cavalry were camped along streams where animals could be watered. In brief, the army utilized the natural water resources of the country in a manner to involve the smallest possible amount of new work.

Conditions in Early Part of This War.

In this war, existing sources of water supply in the areas occupied by the armies have generally been inadequate for the concentrations of troops, and many of them have of course been destroyed or rendered useless. As the war progressed, the procuring of a suitable water supply became increasingly difficult, not only of potable water for men, but water for animals. As a result, both French and British armies found themselves under the necessity of establishing special services to take care of these requirements.

During the early part of this war, Allied troops were forced to face enemy troops in regions where water was very scarce. The troops after exhausting all local water resources would travel kilometers searching sometimes in vain for water for themselves and their animals. They would sometimes dig wells, but with no assurance of finding water. The troops located in the valleys might be able to find water, while those on the higher ground would not. All of these efforts, however, lacked coördination. The changes which followed in the course of battle further increased the difficulties. Those troops which through unusual ingenuity had sometimes managed to secure pumps for some of the shallow wells they had dug, might change their location and occupy a region entirely different in character, — a plateau perhaps, — and find there deep wells from which the pumps had been carefully removed by some one else. As in such cases it was impossible to use pumps except of a certain type, the troops could not utilize the material at their disposal, and were left without the water they were searching for.

The watering of horses was always a matter of the greatest importance and difficulty. When mounted troops are in the

proximity of an important river, the watering can sometimes be easily accomplished without special equipment. If only a small stream is available, large numbers of horses muddy the water seriously and make dangerous mires in the watering places, and the horses refuse to drink, or drink badly. It is possible to build small dams in such streams, thus forming basins in which the horses may drink with smaller danger of muddying the water. But there is always other work requiring time and personnel, and the tactical units hesitate to undertake work of this kind when they expect their stay to be of short duration. The condition of thirsty animals is more distressing to see than is the condition of thirsty men. Animals will lick the side of a water trough as though to quench their thirst, when water is not available. They lose their strength and can do only a fraction of their proper work when very thirsty. In the Champagne region, in the early part of the war, great numbers of animals are said to have died from thirst.

Early Steps by the French and the British.

In the French Army, the importance of adequate preparation for water supplies was not fully appreciated until the summer of 1915, when large numbers of troops were concentrated between the city of Rheims and the Argonne, with the purpose of undertaking certain offensive operations. A serious shortage in the water supply then developed, — so serious in fact that the abandonment of the contemplated offensive seemed to be necessary. In this emergency the first steps were taken toward the development of the French Service des Eaux which has operated effectively since that time.

I recall the French attitude at the time we were getting ready for the St. Mihiel offensive. Along about the middle of August, 1918, we got orders that preparation must be made in a very limited time for taking care of the concentration of troops that was to be made for the St. Mihiel offensive. They expected to concentrate some 500 000 or 600 000 men, and something approaching 200 000 animals, in a section of the front about 22 miles long, all north of what was called the Toul sector. It is a dry sector.

A large part of it lies in that portion of the front which was so frequently referred to in press dispatches as the Woevre. It is a broad, flat plain, largely of clay, in which there is little or no ground water until you penetrate to a great depth. There were dug wells in the region which afforded suitable supply for the use of a local community, — a few people and a few animals, perhaps. But to get in there with a hand pump and try to water horses out of them, — a single, small hand pump will often exhaust the capacity of a well like that in a few minutes, and the replenishment capacity is practically *nil*. When we started in on this job and told our French officers what we had ahead of us, that we had to provide water in that region for 600 000 troops and 180 000 or 190 000 horses, the answer of the French was, "*C'est impossible! C'est impossible! Il n'y a pas d'eau!*" "There is no water." And that was their point of view at the very outset. Well, we had to show them by the procedure we had developed that it could be done, and we proceeded to do it. But the French all the way through were very sparing in their provisions for water. In that respect the British differed in a very important degree from the French, and, likewise, we differed in an important degree from the French.

In the beginning, because of the limited material available, it was necessary to improvise much of the equipment required. The value of these first French emergency installations was found to be so great that their use had been continued, and until the termination of hostilities these water stations could be seen all along the western front covering a zone from just in rear of the front-line trenches to a depth of many miles toward the rear. Many of them have been under artillery fire, as their visibility and their importance often made them good targets, and many of them were damaged by shell fire over and over.

The reports of the operations of the French and British Water-Supply Services discuss water supply both for a stationary army and for an army on the move. These reports indicate that there should be a systematic series of water stations along the rear of such an army where horse-drawn water carts can be filled for use of the troops farther forward. A common distance for this series of stations has been from 6 to 10 kilometers behind the line.

If at a closer distance and not well concealed, it is sure to draw artillery fire; and if farther away, the haul for the carts becomes too great. Many water-supply developments have been made much closer to the front than that, even in or close to the front-line trenches, where time and conditions of concealment have permitted; but an exposed, unprotected water point could not long exist undamaged if located too near the front in an active area.

For a command advancing through country poor in water, both French and British have used automobile and horse-drawn tank wagons which followed up the troops and distributed the water to forward reservoirs or to the horse-drawn water carts, until the troops had again come to a standstill, enabling new water stations to be constructed to supply these forward areas.

These installations are always simple, being made up of such of the following elements as are necessary for the particular location: A small pump and motor, commonly driven by gasoline, if power is required; a simple wooden shack, housing the pumps and attendants; apparatus for the treatment of the water if needed and if conditions permit; a tank suitably located close to a highway; pipe lines as required; horse-watering troughs, and facilities for the drawing of water from the tank into water carts or other containers.

The French authorities have gone on the principle that all water supply should be considered as polluted. The colon bacillus is in fact present in a large proportion of all natural sources of supply in the army areas. Simple and effective methods have therefore been devised by the French Service des Eaux for the hypochlorite treatment of water, and a laboratory service under the Service de Santé determines the sanitary quality of the water from time to time and posts signs to indicate the quality.

The British authorities, too, have assumed that the health of the troops demanded the treatment of all water supplies unless proven safe. They have therefore made a practice of dosing water supplies with hypochlorite, but this has been done to a large extent by hand, at cart-filling stations, etc., and less use has in general been made of special or automatic devices for the applications of the dose than in the French service.

When the armies are at a standstill, as they were during the

two or three years of trench warfare on the western front, the work of the Water-Supply Service is not a complicated matter. It has consisted simply of a progressive development of water stations and their operation and maintenance. The difficulties of the Service arise during an offensive. Many water-supply facilities are destroyed, wells and springs are fouled or possibly even poisoned, and streams polluted.

I might say right here, though, that after a long and careful inquiry from many of the British and French water-supply authorities, an inquiry which I was delegated to make on an official basis, I could find no evidence of the actual poisoning of any water supply by the enemy with alkaloidal or other violent poisons. There are numerous cases of fouling of wells by dumping manure or dead animals into the wells, but that was a gross fouling that one could detect without the use of any laboratory apparatus. But, so far as the poisoning of wells in the commonly understood sense of the word, there are no authentic records of it, in spite of the fact that the newspapers have talked a lot about it.

The concentration of troops and of animals is large, and provision must be made for them, often under severe fire, within a few hours after they have moved over new territory. The wholesale transportation of water by automobile tank trucks is then brought into play, and as rapidly as possible well-digging crews, and crews for the installation of pumps, tanks, hypochlorite apparatus, horse troughs, etc., move forward as fast as possible to establish new water stations. Many such stations are erected and put in service in the course of a very few hours.

The chief of the Water-Supply Service of the Fourth French Army has stated the principle that an army never constitutes a mass sufficiently dense, and whatever idea one may have as to duration of the war, the immobility of the army will never be sufficiently prolonged to necessitate extensive developments of water, but that the greatest possible use must be made primarily of local resources.

The French developments indicate a closer adherence to this principle than do the British. The water points throughout the French Army areas are characterized by their large number and small size, their simplicity, and even their crudeness to some

extent. On the British front, on the contrary, the water developments have been fewer in number and of decidedly larger capacity and of greater extent. Developments having a capacity of a quarter to a half million gallons per day were not uncommon, and some of these had pipe lines running to total lengths of 15 to 20 miles, supplying numerous water points.

The difference in character of the water resources of the regions has undoubtedly had some influence on this. In the regions of the chalk of northern France in which the British armies were to a large extent located, wells could be bored very easily, and large yields secured, — yields running from 50 to 100 gal. per minute, or sometimes even more. Through the regions principally occupied by the French armies, on the contrary, conditions were much less favorable for securing good supplies from wells. Many wells were bored but with greater difficulty than in the chalk, and the yields of such wells probably averaged not more than one quarter the yield of the average wells in the chalk.

The first American contingent arriving in France after the United States entered the war, upon finding these conditions existing in the French and British armies, recommended for the American Army the establishment of a Water-Supply Service to carry on this work for the American Expeditionary Forces. Both the Medical Department and the Engineer Department were impressed with this need. A letter from the chief surgeon, American Expeditionary Forces, to the Commander-in-Chief, indicates the basis for this recommendation, and the chief engineer, American Expeditionary Forces, at about the same time, secured from the French authorities a statement prepared by the chief of the Service des Eaux, covering in general terms the principal requirements in personnel and material which the French service had found necessary for its work.

The War Department complied with these recommendations by authorizing a special service regiment, the 26th Engineers, for water-supply work, and by sending to France certain officers who had had sound experience in the various phases of this branch of engineering.

Early Water-Supply Activities in the American Expeditionary Forces.

The officers who were selected by the War Department for their water-supply experience, and sent to France in the midsummer of 1917, set themselves to the task of inquiring into and preparing to meet the water-supply needs of the American Expeditionary Forces. From an early date, it was clear that the water-supply activities of the American Expeditionary Forces fell naturally into three groups:

1. Water-supply work for the armies.
2. Water-supply work for the S.O.S.
3. Supply of materials for water-supply work both for armies and S.O.S.

It was obvious that during the early part of our service in France the water-supply work of the S.O.S. must constitute by far the larger volume of work. Active work in the field for the Water-Supply Service of the armies would commence only with the armies' assumption of responsibility. For a number of months, therefore, the water-supply work consisted of developments for hospitals, small towns, camps, depots, railways, port developments, etc.; and in this the entire water-supply force was engaged, including the first companies of the 26th Engineers, Army Water-Supply Regiment, after their arrival in France.

Activities of the Water-Supply Section, O.C.E.

Inquiries regarding water-supply programs of the allied armies were started at an early date, and the substance of these is outlined elsewhere in this report. The water-supply needs of the army were considered with great care, and the question of organization and of relations and duties of the army water-supply officers inquired into at length with numerous officers whose opinions were considered of important value in fixing such a policy. This resulted in the issue of Bulletin No. 55 and of General Orders 131, which have since formed the basis of procedure in army water-supply work.

A number of type plans were developed as a result of study of British and French water-supply facilities. An extensive inquiry was made into the question of water resources, especially ground water in the region commonly referred to as the American sector, which the American armies were expected to occupy. A comprehensive report was made upon this, parts of which have been of great use to the army Water-Supply Service in the field.

A consideration of the various reports and observations relating to the water-supply work of the allied armies resulted in the compilation of certain notes intended to comprise the fundamental principles which various water-supply developments for the army should follow.

The question of the kind and quantity of materials for the work was given constant study, and also the program that should be followed regarding production, shipment, storage, and issue of various kinds of materials. When depot shops were established, a certain amount of special manufacture was started of products which were otherwise difficult to procure, and for which the shops had the facilities. The laboratory and sanitary inspection branch was developed, demanding the constant attention of an assistant well versed in those phases of water-supply work, and involving close touch and clear understanding with the Medical Department. Considerable attention was given to the question of treating water supplies by means of liquid chlorine, and the specialized nature of the equipment required for the purpose necessitated bringing to France officers with special experience in this line.

The success of water-supply work in the army depends primarily upon the supply of proper material. The Water-Supply Section of the Office of Chief Engineer has worked in close touch with the Engineer Supplies Section on this matter, and it has been found highly desirable to maintain this relationship as closely as possible.

The supply of materials for water-supply work has involved in the past and will continue to involve many questions which are equally important to the work of the armies and of the rear. Materials for both of these services will come from a common stock in the depots. There were special forms of material which were used exclusively by one or the other; but a very large part of the stock was for common use.

In order that *both* services can be assured the materials they require in proper kind and quantity, and in order that one service shall not through design nor through inadvertence exhaust the supply of materials for which the other may have urgent need, and in general in order to guide certain phases of the problem of the supply of materials for water-supply work in a well-coördinated manner, the control of much of this can to good advantage be exercised by a single office. In France, this was done by the Office of the Water Supply Section, Chief Engineer's Office.

In developing an organization for activities of the magnitude of those in France, it was necessary to anticipate the need for water-supply officers who were to fill the most responsible positions in the field. With this in view, a number of experienced officers were brought over from the United States, held for a time in the water-supply office at General Headquarters, when they gradually worked into various permanent assignments in the field or office.

Outline of Field Responsibilities of Water-Supply Service.

The early field service of the water-supply organization practically began about February 1, 1918, with reconnaissances including the front of the French Eighth Army from the Moselle River westward to the Côtes-de-Meuse, and of the French Second Army from Côtes-de-Meuse, around the St. Mihiel salient, to Troyon, on the Meuse. During this period, American divisions were operating tactically under French Corps, and the French Army water services were carrying the water-supply responsibility.

The first responsibility of the American Water-Supply Service was that of the First U. S. Corps, which utilized first half and then all of Company B, 26th Engineers, on the Toul front, from the middle of May to the middle of June, 1918. This month, however, it was a matter of an American corps representing the American Expeditionary Forces doing water-supply work for divisions which, in turn, remained under the tactical control of French corps.

The same condition remained when the water-supply control was shifted from First U. S. Corps to First U. S. Army, about the middle of June, and extending to about the middle of July. During this period it even happened that once the American Water-Supply

Service had taken over the responsibility for the Toul front from the French Eighth Army the American service continued to function even though temporarily French divisions might be occupying part or all of the area.

One thing that appeared perfectly clear from the outset over there, was the importance of territorial continuity in the work. It was exceedingly important when one water-supply service took charge of the water-supply activities of any part of the combatant zone that they should continue in that capacity more or less indefinitely. Shifting of responsibility for a technical service like the water supply meant a lot of confusion. So, in this instance, as I say, once we had taken over the responsibility for the water supply for the Toul sector, before the Americans had complete control and responsibility for it, we continued handling the work there even though some of the time French divisions were moving in and out and occupying parts of the sector.

From the middle of July, 1918, to the middle of August, 1918, the Second U. S. Army took over the functions of the First U. S. Army in the Toul area, continuing to about the middle of August. About August 1, water-supply troops consisting of about 80 men of Company B, 26th Engineers, and all of Company A, 27th Engineers, took over partial water-supply responsibility in the divisional area of the neighborhood of Baccarat.

Likewise, about August 1, the First U. S. Army Water-Supply Service began to function in areas, in the Château-Thierry region occupied by American corps, operating tactically, however, under the French Sixth Army.

About the middle of August, the First and Second U. S. Armies headquarters organizations changed places, and the First U. S. Army began its St. Mihiel operation as covered in detail in the W.S.S. Report of that army. The Second U. S. Army headquarters organization, on the other hand, operating as the "Paris Group," became of decreasing importance in the Château-Thierry region until, about September 10, 1918, the last of Company D, 26th Engineers, was entrained and brought into the Argonne-Meuse area.

At about this same time, Second Army took over independent responsibility for a portion of the American front in the Toul sector,

and the available personnel, equipment, and material for army water-supply work was apportioned between the two armies in general accordance with the magnitude of the military operations which immediately confronted them.

Upon the creation of the Third Army to go forward to the Rhine after the signing of the armistice, two companies of army water-supply troops, with certain companies of other special service army engineer troops, were assigned to form a provisional regiment, and the water-supply work of the Third Army was handled by that organization for a time, until it became evident that its services were no longer necessary, and it was sent back with the balance of the organization to Bordeaux, and ultimately back to the United States.

Interest of Two Departments in This Work.

One of the first questions to loom up as important in the determination of a policy regarding the handling of water-supply work was as to the respective duties of the Engineer Department and the Medical Department in this matter, in which both departments are so vitally interested.

The Engineer Department has important responsibilities relating to the investigation, design, and construction of works for water supply, and other matters closely related thereto. For a decade or so past, water-supply engineering practice in the United States has given very complete consideration and attention to water-supply laboratory work in connection with the engineering phases of the work. The laboratory examination, sanitary inspection, and other phases that pertain primarily to the question of the quality of water supplies, are so intimately related to their design, construction, and operation, that it is practically impossible to separate them. On the other hand, the Medical Department has certain highly important responsibilities in connection with the quality of water as actually used by troops. All who have come in touch with the problem appreciate fully the fact that these two merge into one another.

The water for the supply of American troops will of necessity be taken from various sources, some of which may be, but many

of which will not be, safe to drink without treatment. Second only to the duty of supplying an adequate quantity of water at the time and place required, is the duty of supplying as good a quality as practicable. This is done by the water-supply organization where conditions justify, by disinfection treatment of the water by means of hypochlorite of lime or liquid chlorine, or by filtration where conditions indicate that to be possible and especially desirable.

The Medical Department, U. S. Army, has an established procedure for the treatment of water, consisting of the addition of a capsule of hypochlorite of lime to a measured quantity of water in the Lyster bag. This is or should be well known to every medical officer of a tactical unit.

Under the conditions of service in the field, it will in most cases be impossible to assure a supply of water to the troops which will be safe to use without further treatment beyond the water points. In the S.O.S., town water supplies will frequently be found which are safe to drink without treatment, and, after laboratory evidence has been secured to demonstrate this, there has at times been a disposition to authorize the use of such a supply without requiring treatment in the Lyster bag.

Universal Need for Treatment of Water.

As time has gone on, the impression has grown stronger and stronger in the minds both of the Medical Department and of the Water-Supply Service of the Engineer Department, that the rule should be laid down and insisted upon that all water should be treated with hypochlorite in the Lyster bag in the prescribed manner, regardless of the fact that it may in many cases be of good quality and safe for use by the troops. The fundamental reason for this is the necessity for water discipline. If troops get into the habit of drinking water without treatment, even though it may be known to be safe and pure, they will not appreciate the need for caution in this matter in other locations where the water may be unsafe to drink without treatment. They may either fail to get instructions, if instructions are given which indicate some new supply to be of inferior quality; or in spite of such instructions

they may fail to appreciate the possibilities of danger and drink freely of a dangerous water because they have not been in the habit of seeking water invariably from prescribed and treated supply.

If, on the other hand, there are no exceptions made to the rule that all waters be treated in the Lyster bag, there will be no interruption in the efforts of the authorities to require the use of water so treated, troops will be more likely to retain the habit of using water only from the Lyster bag, and it will be easier to assure a maintenance of discipline with respect to this matter because of the uniformity of the rule.

The question of water discipline is one which affects not only the soldier who goes looking for water to drink, but it affects also the soldier or officer who is charged with the responsibility for thus treating the water.

The concensus of opinion is that there should be only one exception to such a rule. If a considerable number of officers and soldiers are located more or less permanently in a town which has a public water supply of first-class quality, and are scattered through the community in such a way as to make the enforcement of the Lyster-bag rule impossible, it would be a proper procedure to announce that the water could be used without treatment. This might apply especially to important or permanent headquarters.

Wholesale Purification of Water where Possible.

The fact that a supply is to be treated in the Lyster bag before being used by troops should not cause the proper authorities to neglect the wholesale treatment of any water supply that is known or suspected to be polluted where the conditions justify such central treatment. The existence of a uniform regulation prescribing that all waters shall be treated before being used by troops, will not prevent a fairly large proportion of the troops using waters which either have not been treated at all or which may have been only imperfectly treated. Also, in many a town whose water supply is of doubtful quality, company kitchens and camps may be well provided with Lyster bags in which the treatment is regularly and effectively carried out, but soldiers who work elsewhere

in these towns cannot be expected to return to the location of these bags to get water to drink, but will drink from whatever source is convenient. In other words, the policy should be persisted in of treating at a central point all supplies that furnish water for a considerable number of troops, if the water is of doubtful quality and if the conditions justify the installation of apparatus.

Important Medical Department Responsibilities.

The responsibilities of the medical officer of a tactical unit include the treatment in the Lyster bag of all water supplied to his troops. This is a responsibility which cannot be taken by the water-supply organization. The medical officer with the tactical unit cannot and would not be relieved of it. Neither would he be relieved of the responsibility for assuring water of satisfactory quality in water carts, water tanks, or containers other than the Lyster bag, in the event of any conditions which permit the unit to use water in other ways than through this bag.

The control of this feature of alimentation has long been acknowledged as one of the Medical Department's most important functions. In the last analysis, they *cannot be* relieved of responsibility for this phase of the care of their troops. The medical officers of tactical units will in general feel safe only by satisfying *themselves* as to the quality of the water they are getting for their troops, and by seeing to its proper treatment through all the means at their command.

It is necessary to draw some dividing line between the responsibilities of the medical officers with troops and the water-supply organization. This division of responsibility must be so clear and simple that there will be no confusion in the minds of those whose duty it is to administer the details of the procedure.

Division of Responsibility.

Based upon the above premises, a logical division of these responsibilities would be as follows: the water-supply organization to make available adequate quantities of water at water points located as conveniently for the troops as the conditions

reasonably permit, and in as pure a state as practicable, using filtration or disinfection treatment, or both, as circumstances may justify; the medical officers attached to tactical units to attend to such subsequent disinfection treatment as the water may require, in the Lyster bags, in water wagons, tanks, or reservoirs from which water will be drawn by individual soldiers for direct consumption, etc.

This basis is the most logical one, since the responsibility of the water-supply organization in the construction of works and handling of the water terminates at the water points; whereas the responsibility for the transportation of the water from the water points to the final point of use, in cans, or pails, or water wagons, etc., rests upon the tactical units themselves.

The weight of these arguments was recognized in the discussions that took place between representatives of the two departments, and after concurrent approval by chief engineer and chief surgeon, American Expeditionary Forces, a general order was issued, G.O. 34, G.H.Q., 1918. This was later modified to make it clearer and more comprehensive, as G.O. 131, G.H.Q., 1918.

Numerous questions of procedure regarding points of mutual interest to the Engineer Department and the Medical Department were raised in the course of the discussions. The defining of responsibility in the general orders made it necessary to make the authority coincide, so that officers engaged in the discharge of Engineer Department functions would be assigned to and be responsible to that department. The occasion for specifying this arose out of the development in the Engineer Department, as a branch of the Water-Supply Service, of the laboratory and sanitary inspection branch. Much of its personnel was drawn from the Sanitary Corps of the Medical Department, and some of the water-supply laboratories were located in Medical Department laboratories, where otherwise there would have been a duplication of facilities.

This official designation of responsibility and authority should not interfere with the services of the officers of the laboratory branch, being of the maximum usefulness to the Medical Department as well as to the Engineer Department. With a full recognition that the water-supply problem is one which involves the

interests of both departments in a peculiar way, the duties of the laboratory branch are intended to include everything that either the Engineer Department or the Medical Department may want to cover in connection with questions relating to the quality of water supplies, and it must be fully and specifically provided that the information regarding the quality of water supplies shall be made fully available to the Medical Department.

The most careful consideration has been given to this rather mixed problem from the first, and the Medical Department freely consulted, with a view to arranging a procedure which would be understood and recognized as sound by both departments.

Establishment of Water-Supply Laboratories.

A laboratory branch was established with headquarters in Paris, where it has remained, owing to the connection which the officer selected to place in charge of the laboratory branch has had with certain work of the Interministerial Commission in French government laboratories. Upon the removal of headquarters, S.O.S., to Tours, a branch laboratory was established in Tours, to handle both sanitary and industrial analysis of water in that vicinity. Subsequently, water-supply laboratories were established either as parts of Medical Department laboratories or as independent laboratories under the Water-Supply Section at the following points: St. Nazaire, Bordeaux, La Rochelle, Dijon, Neufchâteau, Brest, Nevers, Le Mans, and London in the S.O.S., and also several movable laboratories were established in the army zone.

The personnel for this laboratory branch of the Water-Supply Section is made up partly from the Engineer Department and partly from the Sanitary Corps of the Medical Department, as both officers and soldiers having the requisite special training and experience are found in both departments.

The matter of reporting laboratory results was taken up very carefully in order to make it simple and systematic. Procedure was followed which resulted in complete records of all analyses being transmitted promptly from the engineer organization developing them to all the authorities who were vitally interested in the problem, — that is, the several medical department authori-

ties in positions of principal responsibility in the jurisdiction in question, — and also to certain engineering authorities within that jurisdiction. Maps were likewise prepared showing the location of all water points, the nature of those points, — that is, the facilities included in those water points, — and, where possible, some note regarding the quality and the capacity of the supply. These were printed in large numbers and circulated to all the authorities interested, especially to the responsible officers of tactical units coming into the area. For example, west of Verdun, between the Marne and the Argonne, maps were prepared from time to time as we occupied successive parts of the terrain. A map was prepared to be correct as of a certain day, was brought up to date during that day, and sent back to one of the army printing establishments, where the base prints already on hand were completed by the superimposing of the data on the revision of the water points, and a large number of up-to-date maps thus prepared were gotten back and distributed in the field within a remarkably short period, — a matter of only a few hours. So that new divisions or other units coming into the area for active operations within the next few days could have ready at hand in the most usable form all possible data regarding location, and capacity and condition of water-supply resources.

Standard Methods of Water Analysis.

Water-supply laboratory work in the United States is done on the basis of standard methods developed by a committee of the American Public Health Association. These standard methods were not considered suitable for the use of the American Expeditionary Forces, and the question of suitable methods was given lengthy consideration on the part of the various officers of the Water-Supply Section who had had extensive laboratory experience; on the part of the laboratory branch of the Medical Department; with due consideration for certain methods in current use by the French authorities of the Service de Santé; and also not less important, with proper consideration for reducing time and equipment to a minimum.

Field Laboratories.

Reference was made to the fact that the laboratories used were of two types, fixed and movable. A laboratory that can be easily transported from one scene of activity to another is especially valuable, even indispensable, in army water-supply work. This was foreseen when provision was being made for this work in Washington in the summer of 1917, and four special water-supply laboratories were designed and built, mounted on light motor trucks. They reached France in time to be used throughout our activities of the summer of 1918, and proved to be very useful.

Experience showed that the motor-truck feature of the laboratory was not of great importance, as a laboratory did not move often. In fact, in view of the serious shortage of motor transportation, it was a temptation to lift the body containing the laboratory complete, off the chassis, in order that the latter might be made use of. This was actually done, and the laboratories thus dismounted were used for long periods as fixed laboratories.

The Poisoning of Drinking Waters.

The poisoning of waters by the enemy upon returning from a region has always been looked upon as a possible menace to the safety of troops. In this war, preparation was made, both by the British and the French, to guard against this danger. Both of those services provided their units with suitable testing outfits, which have been used to some extent.

When the American Water-Supply Service made inquiries about this, with a view to determining their own program, no authenticated cases of the chemical poisoning of water supplies by the enemy could be found, in either the French or the British services. As a result of this, the practice of making routine toxicological examinations of newly acquired water supplies has been carried out only irregularly, and in some regions not at all.

The armies of each nation, however, are supplied with the apparatus and personnel necessary for carrying out these examinations, poison-test kits being placed in the hands of properly qualified medical officers. They should by all means be available,

but more as a preparedness measure against the possible future use of poisons by the enemy than because of any practical utility at the present time.

Owing to the difficulty of poisoning water supplies, on account of the added poison being washed out by the natural flow of water, the difficulty of collecting samples during the confusion of an advance and the difficulty of properly guarding a well from thirsty men while a toxicological examination is being made, the feeling has grown up that the toxicological examination of newly acquired water supplies will never become an important problem.

Need for a Recognized Policy and Procedure.

The prospect of a demand for water-supply work in the army zone, emphasized the importance of getting, at as early a date as possible, a clear decision of the question as to whether the Water-Supply Service should be an army service strictly, operating directly under the chief engineer, army, or whether it would be an army service only in name, but operated to all intents and purposes as a corps organization. It was believed, as a result of much discussion of this subject, that the most effective work could be done by the Water-Supply Service if it operated with a direct control from Army Headquarters. The French Service des Eaux operates in this way, and affords one of the best evidences we have of the propriety of this procedure.

It was assumed from the outset that the Water-Supply Service ought not to be attached to the division. The territorial jurisdiction of the division is very transitory. A division may be at one place only a few days. The corps is even less mobile than the division. It is, however, still mobile in the sense that its geographical boundaries may change, especially in connection with great activity. This may be accomplished in a manner different from the bodily movement of the division into or out of an area; perhaps by orders which alter the number of divisions in a given corps, or some other relatively simple procedure which has the effect of altering the territorial boundaries of its jurisdiction. If water-supply troops and water-supply officers belong to corps, there would then result a sudden change in jurisdiction which

could be accomplished only with difficulty and lost motion, in changing the control of work which pertains so distinctly to the area, rather than to the tactical unit. Such changes as this would be most likely to occur at times of great activity. Then, of all times, continuity of control is of dominating importance to maintain.

Further, it is recognized that in the development of water-supply work, one system may with advantage supply troops in two corps areas on opposite sides of the common boundary line between corps, due to topographical or geographical conditions. Pipe lines may cross these boundaries. One pumping station may serve points in two areas. An ample source may be available on one side of the boundary line, and nothing readily available on the other side. These conditions all point to the desirability of a control of water-supply work from Army Headquarters.

Need for Continuous Territorial Jurisdiction.

Water-supply work is dependent upon topography and other factors which tie it definitely to the ground. Divisions are mobile, and the tendency is to make them more mobile rather than less. The territorial jurisdiction of the divisional commanding officer and divisional chief engineer is transitory. In moving into a new area they are sure to be extremely busy with other functions which pertain practically entirely to tactical problems. Water-supply projects should be systematically looked out for by a responsible organization which has a geographical constancy. This development will be under way before a division comes in, continued during its presence, and completed often after the division has left a given area. The division furthermore has a right to expect work of this sort to be done for it by some other agency, and should not be burdened with any real responsibility for this development.

The only definite control which should be exercised by corps or divisions should be that which fundamentally belongs to them, as for example, police control, traffic control, and near the front, measures for safety.

An important factor in deciding this question was the fact that

the Service des Eaux of the French Army operates on the basis of control from headquarters army. The corps, in general, has no responsibility for water-supply work, except to indicate its needs to the Water-Supply Service, if not already foreseen.

Army Control, Bulletin 55.

This matter was finally covered by the issuance of Bulletin No. 55, G.H.Q., 1918, definitely placing the water-supply troops under the chief engineer, army, with a direct control over the water-supply work throughout the entire army area. Provision is made for assuring that the wishes of the corps or division engineers in water-supply matters be given the greatest possible consideration consistent with primary control from the Office of the Chief Engineer, Army. This was supplemented by a memorandum of instructions from the chief engineer, First Army, to the commanding officers of special engineer units, emphasizing the imperative need of keeping in constant touch with corps and division engineers in such a way as to assure the fullest possible compliance with their wishes.

Component Parts, Army Water-Supply Service.

The experience of several months' activities of the American Army in France has shown that an army Water-Supply Service should consist of the following:

1 regiment of army water-supply troops.
1 water-tank train, complete with personnel.
1 M.T.C. mobile repair unit, complete with personnel.
General engineer depot shop trains and trucks.
Additional labor troops.
Additional officers for staff and special duty.
Water-supply laboratory branch.

The combination of such labor troops as are required, with an engineer regiment having specialized training of personnel, makes for flexibility and efficiency. The water-tank train serves the vitally important purpose of wholesale transportation of water in

situations that do not permit the prompt supply of water in any other manner.

It was by means of our water tanks, which at that time were organized and ready to do business, that we overcame the difficulties that our friend, the French liaison officer, feared when we started to get ready for the St. Mihiel offensive. When they said it was impossible we knew it was possible, because we had carrying capacity for some 60 000 gal. of water on wheels at one time. And we worked that hard; and this was the only means, by the way, which could have kept the armies supplied with water in the dry area. The improvement of the quality of the water, where conditions justify it, or at least the inspection of water supplies and their laboratory examination, and the spreading of helpful information regarding quality, is assured by the laboratory branch. The maintenance and repair of all motor-truck equipment, in prime condition for use at any time a period of activity of army is announced, can be accomplished by the presence of the M.T.C. mobile repair unit. The G.E.D. shop trucks assure independent ability to handle almost any of the varied kinds of mechanical work the water-supply service encounters in the field.

Regiment of Water-Supply Troops.

The regiment of army water-supply troops, the 26th Engineers, was organized at Camp Dix, made up to some extent of volunteers, and to some extent of men especially selected from the draft, for their knowledge and experience in water-supply work. They were brought together and given some preliminary training, which was of a purely military nature, in Camp Dix, before they went to France. An effort was made to select them carefully. There was a demand for these companies in France very early in the fall of 1917. When the first demand was made from France for some of these companies to go over and go to work, the companies had not yet been recruited up to their proper strength with special personnel, and the authorities simply threw into the organization such miscellaneous labor troops as they could find handy and sent the whole bunch over. As a result, the first two companies that came over were rather a poor assortment. I recall

when they landed at St. Nazaire there was more or less criticism on the part of the authorities who had first to handle them and to put them to work. Criticism, I mean, of the make-up of some of the companies. One point of the criticism turned upon the fact that they had among their number a dancing master, also a candy manufacturer, and they could not quite see what a water-supply organization needed of a dancing master and a candy manufacturer, — no more could I. That was corrected, however, later on.

The regiment had a normal strength of about 1 600 men, with something between 40 and 50 officers. The officers with few exceptions were men who had had considerable experience in water-supply work, and they were really the backbone of the water-supply service over there. Some were sent with the organization, and others as a result of requests for men specially qualified in water-supply work, and these made up the staff organizations to a large extent. I will not attempt to outline the details of specialized training, but you can naturally see that a considerable number of men competent to handle well-drilling apparatus were required, large numbers of men who were familiar with pipe work in all its phases, considerable numbers of carpenters and concrete workers, and so on. The classification would go through a fairly large range.

Just prior to the cessation of hostilities, when things had grown hot enough so that we were stretched to the limit of our capacity and ability with this limited number of specially trained men, we finally got an authorization through the War Department for the creation of a second water-supply regiment, the 228th Engineers. To go back to the early history of it, the first outline at the War Department in 1917 prepared for one such regiment for each army that was to be created. It provided the first regiment in connection with the plans for the First Army. The Second and the Third armies were created in the field, with very little preparatory work, and it seemed as though nobody in Washington took the initiative in organizing and sending over to France the special-service engineer troops which were required to build the complement of each army. That was true not only of the water-supply troops but of all the other special-service troops; and as a result we had to

take our water-supply regiment and the other troops that had learned something about water supply, divide them up, and scatter them all over France. While it was demoralizing to organization spirit, it greatly broadened the scope of our activities, and the service that could be done for the American Expeditionary Forces as a whole. It was very unsatisfactory from a management point of view, however. Owing to the cessation of hostilities and to the suspension of action regarding all further promotions and original appointments, the 228th Engineers was not organized.

Use of Tank Trains.

The water-tank trains are intended primarily for the wholesale distribution of water in areas not yet reached by the satisfactory development of water supplies, such for instance as an area taken by an army in an advance or an area held for a long period under shell fire which is severe enough to prevent the construction or the maintenance of water points.

The water-tank trains were a very important part of the outfit over there. Certain water-tank trains were ordered in this country back in 1917, but did not arrive in France until midsummer, or later than midsummer of 1918. Realizing how indispensable they would be when we came to field activities, we improvised certain water-tank trains for use in the St. Mihiel offensive, and between that time and the time the Argonne offensive commenced, some of our water-tank trains commenced to come in. So that from that time on we had an ample supply of tanks mounted on motor trucks. The water-tank trains as organized — not the improvised trains but the trains ordered from this country — consisted, if I remember rightly, of about 135 tanks mounted on motor trucks, and 14 mobile water-purification trucks, certain repair trucks, and certain other special transportation. Each train had a personnel, including the mechanics, chauffeurs, and others, amounting to about 500.

The special water-purification trucks were of the greatest use and greatest interest. We had over there a total of something like 40 of them, if I remember the figures rightly. With a few exceptions they consisted of a filter, a pump, and a liquid chlorine

machine, all mounted in compact form on a substantial motor truck, and having a delivery capacity of about 1 200 gal. an hour. They were extremely useful.

The French, as I intimated a while ago, had made no use whatever of surface waters. Their developments had been entirely from ground waters. If they could not find a spring or a well, or if they did not have time to dig or bore a well in order to develop a ground water supply, they merely said, "*Il n'y a pas d'eau!*" and that was the end of it. They were astonished when they heard that we contemplated the use of the muddy waters of some of the streams, — streams in which cavalry and artillery horses had trampled and stirred things up to a dreadful degree a mile or so above the point at which we proposed to take the water. But these special purification equipments could be wheeled up into place, a connection dropped overboard into the muddy streams, the equipment set going, and within a very short time it would be delivering a stream of water that was clear, clean, and pure, as determined by laboratory tests. There was a laboratory, incidentally, attached to each of these equipments. It was the saving of the situation, really, in both the St. Mihiel and the Argonne offensives.

The use of the water-tank trains involves filling points having a capacity great enough so that the tank trucks are not seriously delayed in filling. Only a few minutes should be occupied in filling each truck, and the pumping capacity, storage capacity, and piping must be so arranged as to permit this. These filling points must be located where they will be reasonably safe against enemy shell fire and gas, and yet as close as is reasonable to the front, and on or near the main routes the water-tank trains will follow going forward. Alternate filling points should be prepared as a reserve, as far as conditions permit, to be ready in case of interference with the use of the principal points. Routes must be selected leading forward into the areas to be supplied, and due consideration given, so far as limited choice will permit, to conditions of probable traffic congestion. Return routes must also be indicated for use until such time as forward filling points can be established. Reservoirs or tanks must be placed well forward in the regions to be supplied, into which the water can be emptied

from the tank trucks, and to which the nearby troops can come with their water carts, pails, etc., for filling. A schedule of the movement of the detachments of tank trucks should be studied and established. It is recognized at the outset that traffic congestion and other uncontrollable conditions are almost certain to make it impossible to adhere to any predetermined schedule. A systematic program is necessary, however, to assure the best results under the difficult conditions in the field and to aid in the transmittal of orders and information.

If the attempt is made to deliver water from the tank trucks directly to organization water carts, pails, etc., as a retail proposition, the work of the tank-truck detachments cannot be handled as expeditiously as the wholesale delivery to tanks or reservoirs. Furthermore, the obligation for getting water from some local point where it is made available in wholesale quantities rests usually upon the tactical units themselves. Nevertheless, under some conditions in the field it has been found desirable to use the tank-truck detachments as a means for the retail distribution of water, especially during periods of traffic congestion and troop confusion which frequently accompany an offensive movement.

Improvised Water-Tank Trucks.

When the First Army took the field for active operations, the equipment of the water-tank trains had not yet arrived in France. Water-tank trucks had to be obtained, however, and it was necessary to borrow some and to improvise others. A number of trucks were secured from the Quartermaster Corps, intended for hauling gasoline. For the rest, 5-ton trucks were mounted with closed steel tanks, giving a total capacity for each truck of about 1 000 gal.

During the St. Mihiel offensive the filling points were about 10 to 15 kilometers back of the line. A large part of the country covered by the offensive was very dry and devoid of natural water resources. There were practically no springs over a wide area. There were numerous dug wells, and these of course were used to the limit of their capacity; but a single hand pump was frequently enough to exhaust the storage in one of these wells, and the inflow

into the well thereafter was very slow. There were also a number of bored wells, some of which had been put down by the French military authorities. When equipped with suitable pumps, these could be made to give a certain yield — but it was small, running on the average only 10 to 20 gal. per minute. None of them near or beyond the enemy lines were provided with pumps at the time of the offensive, and they did not, therefore, constitute an available resource for some time after the offensive started.

Very promptly after the beginning of the advance, detachments of water-supply troops went forward, keeping as close to the advancing line as possible, and built canvas reservoirs or made other arrangements for containers in suitable locations. The improvised water-tank trains then carried water from the filling points farther back to these forward reservoirs, making trips as frequently as the traffic conditions would permit. As quickly as possible new filling points for the tank trucks were established in the new areas, in order to cut down the length of haul on congested roads.

The special water-purification trucks are not in general of adequate capacity for use as filling points for water-tank trucks, and for this use with the water-tank train they can be considered as valuable only in pressing emergencies. They were put to this use to very good advantage, however, during the St. Mihiel offensive.

In the activities west of Verdun, the water-tank trains were used extensively, and were indispensable in many parts of the region. In order to facilitate the prompt utilization of the detachments of tank trucks, the water-supply companies were very enterprising in the construction of forward reservoirs. The water-supply detachments, with horse-drawn vehicles carrying canvas and necessary tools for the quick construction of these reservoirs, were in some cases the first vehicles to go forward over the roads, following the advance of the infantry lines.

Motor Transport Corps. Mobile Repair Unit.

The quantity of motor-transport equipment belonging to each water-tank train and to the water-supply regiment in an army

justifies the presence of suitable means for maintenance and repair.

Each motor-transport corps mobile repair unit is stated to include the following equipment:

1 5-ton machine-shop truck, carrying a generator set with motor-driven screw-cutting engine, lathe, drills and grinders, hand and machine tools, welding, soldering, and blacksmith outfits, and full equipment of ordinary and special automobile small tools, small repair parts and supplies.

1 5-ton wrecking truck with either derrick or winch.

2 5-ton cargo trucks for the larger and heavier spare parts, such as complete axles, transmissions, etc.

1 ¾-ton cargo truck for equipment of personnel.

1 5-ton 4-wheel tire-press trailer.

1 5-ton stock-room trailer.

1 light 2-wheel office trailer.

1 light touring car.

Shop Trains for Water-Supply Companies.

The water-supply companies engaged on active work in the field have, from the very nature of their activities, a great deal of small shop-work to do, requiring machine-shop equipment, blacksmith and carpenter outfits, plumbing, metal working, etc. The question of working equipment for these companies has two phases. On the one hand, each company must be provided with a suitable assortment and quantity of tools and supplies which will enable a considerable number of working parties to be sent out on different jobs of water-supply work, each properly equipped for its job. On the other hand, there must be facilities at some central point which will enable the company commander to do, without delay, and without embarrassment for lack of reasonable facilities, many jobs of simple shop work, which time and distance and need for conserving transportation and man-power make it impracticable to send to some remote shop, where, even if convenient to send it, shop conditions might not permit prompt attention to each small job. These conditions, experience in France has shown, point to the urgent need of a reasonable shop equipment in the hands of each water-supply company.

The General Engineer Depot in Washington has developed a type of shop train consisting of 4 motor trucks, as designated below, mounted with suitable equipment:

1 machine-shop truck.
1 blacksmith-plumbing shop truck.
1 carpenter-shop truck.
1 supply truck.

One of these trains complete should be considered as an essential part of the working equipment of each battalion headquarters of the water-supply regiment of each army, and in addition, each company should have one fully equipped machine-shop truck.

Additional Labor Troops.

It has always been recognized that the water-supply regiment by itself would not suffice to take care of the water-supply work in an entire army area under all conditions. This would be especially probable in occupying a new area in which no extensive and systematic preparation had been made for water supply, or in occupying an area desolated by the enemy, or in active preparation for an offensive.

At such times as these, additional troops are required. In order to meet the water-supply requirements of the First Army during its preparation for the St. Mihiel offensive, certain companies of the 27th Engineers (mining), and the 37th Engineers (electrical and mechanical), were attached to the 26th Engineers, bringing the total working force on water supply in that area up to approximately 7 companies. The companies of the 27th and 37th Engineers were not selected primarily because of special qualifications, but rather because they were available and not otherwise engaged on any important work.

During the offensive between Verdun and the Argonne, three companies of pioneer infantry were temporarily assigned to the Water-Supply Service, and attached to the several companies of the 26th Engineers operating in that area. The substantial increase in labor thus resulting enabled the skilled labor of the water-supply companies to extend further and be more effectively used. The results of thus attaching pioneer infantry have been

satisfactory, and this must always be considered an essential feature of the army Water-Supply Service.

Labor troops are valuable in proportion as the warfare becomes one of fixed position.

Additional Officers for Staff and Special Duty.

The various activities of the office of the water-supply officer, army, demand a suitable force of energetic, enterprising officers who are experienced in the fundamentals of water-supply work. Besides the water-supply officer, whose responsibilities and duties are heavy and exacting, a principal assistant or deputy is required; also a supply officer, who may be the regimental supply officer, but whose duties will be far heavier in connection with the supply of materials for the army water-supply work; also a water-supply intelligence officer, to follow constantly all possible sources of information relating to water resources in the region occupied by the army and to guide in a general way the outlining of the broader phases of the program for water supply for the entire army; also an officer charged with responsibility for the water-supply laboratory and sanitary-inspection phases of the army water-supply work; also an officer to handle the general administrative work of the office and of the regiment, probably the regimental adjutant, with such assistance as he may require. The above list of officers for an army water-supply organization is the result of experience under the conditions our armies have met. Other conditions might demand considerable variations from this list.

Large Quantities of Materials Required.

I recall the conditions that existed on the British front after the Boche drove the British back toward Amiens early in 1918, and then later in the summer when the British drove the Boche back over the same territory. There was an enormous loss of material. In the British retirement toward Amiens they left behind, of course, practically all of their equipment in the field. They were able to salvage a little bit of the movable equipment, pumping machinery, and light stuff, — but very little, because

they were driven back very rapidly. It was to all intents and purposes a dead loss. And also large quantities of material they had stored within a few kilometers of the front was a dead loss. They had then to establish their water supplies for their combatant forces in the new positions which they had to take up, where they had been driven back.

Then a few months later, when they made the advance and drove the Boche back to and over the Hindenburg line, the whole area had been practically denuded of its water-supply facilities, because the enemy had taken special care, as he went back, — and he went back a good deal slower than the British had — to wipe out every bit of useful equipment. There they were, then, faced with an advance over an absolutely desolate area, nearly as desolate as a floor as far as water-supply equipment left there by the Boche was concerned. The water resources were there in the holes down in the ground, many of which they did not destroy. This, of course, meant the consumption of a large quantity of brand new material, and the installation of new water points. The rate of consumption of pipe and of pumps and all other equipment in connection with movements of that sort is simply astonishing. I won't give you any figures except just one to illustrate its magnitude.

In our plans for the future — we were then faced with the possibility of something of that sort ourselves if the war should go on for many months more, and if we too should be subjected to a serious backward movement, and we therefore considered it prudent to take the highest figures — that is, figures based on the worst conditions that the British had been subjected to — as a basis for our estimates of quantities of pipe and of pumps that we ought to put on order, especially as it took anywhere from eight months to a year from the time of writing an order and putting it into the hands of the staff in France, until we would actually get the pump or the pipe on the ground ready to put into place. Therefore, with eight to twelve months' time to get deliveries, you can see we had to make provision, and ample provision, for a large margin of safety. So that the one figure I was going to quote you was this: We had on order 90 miles per month of 4-in. steel screw pipe, and that was based on the actual

loss and consumption of the British during their severe campaign of early 1918.

Water Consumption of Armies.

It is, of course, necessary to have some figures of motor consumption set as a guide to an engineering force in the field, to serve as a basis for design where time and the exigencies of field service permit such consideration to be given. In many situations this cannot be done. The quantities that can be made available will frequently be limited by the meagerness of local natural resources, by the shortage of time during hurried preparations for an attack, by limitations of equipment or materials, by imperfect information as to the number of troops or animals to provide for, or by various other conditions incident to the military situation. They may thus bear no relation to the unit quantities considered as desirable.

The Commander-in-Chief, in a communication dated November 15, set a limit for water to be supplied at semi-permanent cantonments and billets at 10 gal. per man per day, and for hospital use 25 gal. per man per day. The data relating to water consumption at British hospitals given in Appendix 20 indicate clearly that 25 gal. is an unnecessarily large allowance for all hospitals. For extensive hospitals of the barrack type, such as the 1 000-bed units and the 300-bed units adopted as standard by our Medical Department, 10 gal. per man per day for the maximum population of the hospital, including patients and staff, should be sufficient.

A consideration of the data given, together with all of our field experience, indicates that for water-supply construction work with the armies in the field an allowance of 2 gal. per capita per day for men and 10 gal. for animals, with proper consideration for special conditions such as the filling of water-tank trucks, light railway cars, etc., will assure quantities which will enable the troops to pursue their activities without suffering for want of water. Compilations of figures for water consumption in the field have been made. They vary widely, some of them being less than the quantities here stated. It is known that large masses of men and animals have under stress of necessity carried

campaigns to a successful termination with much smaller quantities of water than these.

Horse Watering.

The organization tables call for about 7 500 animals, mostly horses, for each division. In addition, when considering a corps or an army, there must be taken into account the animals required for special corps or army service and for trains. Including these additional animals, the total number of animals in each division for which water may have to be provided may be taken as about 9 000. On the basis of 20 combatant divisions per army, this would make, without counting any attached cavalry, about 180 000 animals per army.

The magnitude of the animal problem may be judged from this statement of the Remount Service, that the British had brought about 500 000 animals to France in connection with their military operations, and from the statement in a French report that 175 000 horses were concentrated back of Verdun, and during the advance in the summer of 1915 the Third French Army was provided with about 1 animal to each 3 men.

One of the most important factors of the program for the army water-supply organization is the providing of water for the animals. Animals can, of course, be watered in flowing streams or in ponds, and this is done and must be done to a large extent. An army cannot always depend, however, on finding suitable streams for this purpose. Even if it does find them, they are not a satisfactory means of watering animals, for a number of reasons. Where animals are watered in a stream, certain points that can be conveniently reached by the animals will of course be used. Unless the conditions along the bank of the stream are unusually favorable, these points are likely to become mires after a large number of horses have watered there. It not infrequently happens that horses get down in such holes as these, are unable to extricate themselves, and are drowned.

A flowing stream is also sure to be used as a source of water supply for soldiers, usually with treatment, but undoubtedly to some extent without. It is obviously desirable, therefore, to

prevent as far as is possible the pollution of such a stream. A large measure of pollution can be prevented by providing some other means of watering the animals, thus obviating the necessity for large numbers of animals and men going down to the streams.

Attention to Fundamental Principles.

The layout and the construction of horse-watering points require close attention to a number of important principles to give satisfactory results. First of all, of course, the arrangement of the troughs, their capacity, and the hydraulics of the system, must be considered; the difficulties that may arise from congested traffic conditions must be recognized; other conditions, such as concealment, suitable drainage, protection of roads, segregation of infected animals, etc., are all of varying importance, depending upon local conditions.

Types of Troughs.

Numerous different types of horse-watering troughs have been used by the Allied armies. The most common type has probably been the wooden trough. The French have made these in large quantities, of a simple design which permits indefinite extension of the length of the trough. The French troughs, however, very commonly have the difficulty of too small a capacity. Many of them have been noted which serve well enough for the few horses which use them during quiet periods, but which would be utterly inadequate for large concentrations of horses. British experience has indicated the advantage of having a substantial amount of storage in the trough itself, in order to take care of the maximum rate of watering during concentrations. The British have also used wooden troughs extensively, but there has been considerable restriction on the use of wooden troughs on account of the scarcity of lumber.

Concrete troughs have been used to some extent. The conditions of field service during the periods of activity, of course, do not permit such permanent construction as concrete troughs imply. The Water-Supply Service of the American armies has

not built many concrete troughs. Conditions throughout 1918 have generally been too active to permit of any but the simplest and most hasty construction. Warfare of position, such as the Allied armies were engaged in during three years, more or less, permitted the construction of elaborate and more permanent structures, and there are among the British works, especially, many structures of types which the American Water-Supply Service did not build at all.

Sheet-steel water troughs have been extensively used. The British had certain types of steel troughs which served their purposes well, and the American Army was beginning to make use of them toward the end of our campaign, and had a rather extensive program of production arranged for. Considering all conditions, the steel trough appears to offer the greatest advantages. It is light and durable, and it does not require large quantities of wood. It can be made so that the sections nest, thus reducing the bulk and facilitating transportation, and it can be so designed as to permit of indefinite extension in length. The American Army experience had not gone far enough to crystallize standard types of trough, but the tendency was strongly in the same direction as with the British.

Quantities of Water for Animals.

There are many fragmentary records relating to the quantity of water taken by animals. The conditions vary a great deal in the different statements. It would appear that the average daily consumption of large numbers of horses might be 5 or 6 gal. per head during the thirsty periods and while the horses are at work, and considerably less than that in weather that does not encourage animals to drink much and when they are not working; in a broad way, an assumption of 10 gal. per head per day as a basis for design will assure adequate capacity of the water point. The importance of getting the proper relationship between the varying demands, the pump capacity, and the storage provided, should be emphasized.

History of the 26th Engineers.

There is a large amount of extremely interesting data, the story, as you might say, of the activities of the water-supply regiment in France, which was written up as an official history which now reposes in the archives in Washington. Both officers and soldiers of the organization wanted that history for a permanent place on their library shelves. A program was therefore arranged for a rewriting of it in some more popular form than the dry recital of facts presented to the War Department, and it has been so rearranged, and it is to be published as a paper of the New England Water Works Association. It will not be read before the Association, but I will refer to it now as the history of the 26th Engineers, the water-supply regiment, and their activities in France. It will appear shortly as a separate number of the Journal of the Association.

Discussion.

Mr. Frank L. Fuller.* I wish Colonel Longley would tell us a little bit about the driving of some of these wells, if it won't take too long. I should like to hear about the mechanical work that was done.

Colonel Longley. Very few wells were driven on the American front. Our activities in the combatant areas were moving too rapidly for the driving of wells. There were many wells driven in the work on the lines of communication. There were some very deep wells driven. At Bordeaux there were some wells driven which I think went down about a thousand feet.

Mr. Fuller. How large were those wells?

Colonel Longley.† I think th yestarted with a 10-in. casing and wound up with a 6-in. There was a large flow from them. One of them, I think, delivered a half-million gallons a day. It was a good well.

Mr. Fuller. Any as small as 2-in.?

Colonel Longley. Very few as small as that in the field,

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but on the lines of communication there were many small well points put down. We had a large quantity of well-drilling equipment over there, most of it purchased in the United States, and a little equipment from England, much of which was put to very good service. After the British lost so much of their equipment in the great movement they had to make in 1918, we turned over to them quite a bit of well-drilling equipment. They made much more use of wells than we did, for the reason which I think I referred to as I went along, — the fact that the geological conditions in the areas they occupied were more favorable for getting large quantities of water from wells, which were drilled very easily, because the earth was chalk, and it is saturated with water at a depth not far below the surface. But in all the areas that we were occupying drilling was difficult. The rock was fairly hard, and the yield was small, so that the time element came in there, and we did not do very much development of water supplies by wells at the front.

MR. FULLER. You got the surface water in shape quicker than you could drill the wells?

COLONEL LONGLEY. Yes.

MR. FULLER. Did the Germans do much in that line?

COLONEL LONGLEY. No. I was astonished, really, at the small amount of systematic effort that the Germans seemed to put into their water-supply work.

MR. FULLER. They had to drink water, didn't they?

COLONEL LONGLEY. They used bottled waters to a very large extent, but not exclusively water, Mr. Fuller.

DESCRIPTION, OPERATION, AND PURIFICATION EFFECTED BY DRIFTING SAND FILTRATION SYSTEM IN TORONTO DURING 1918.

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The purification of the water supply for the city of Toronto is effected by means of two systems, one being a slow sand and the other a mechanical of the drifting sand type. The water is drawn from Lake Ontario to the south of Toronto Island, two intakes being situated a little over 2 000 ft. from the shore, submerged in about 60 and 80 ft. of water, respectively. The slow sand system has given excellent results, but when an extension was found necessary in 1914, the city decided on mechanical filtration, the reasons given being, difficulties in operation, caused by a combination of occasional high turbidity and the low temperature in the winter months.

The object of this paper is to give as briefly as possible, a description of the drifting sand system and the results of the operation and purification effected during 1918. Throughout the paper the word " gallons " are Imperial gallons. The capacity of the plant is 60 million gallons in twenty-four hours, but a maximum rate of 72 million gallons daily must be maintained for a period of ten hours. The rate of filtration is somewhat higher than is usual with mechanical plants, the rate being 150 million gallons per acre per day. Before describing the plant it would be well to state the two principles involved in its operation. They are the introduction of a coagulant without sedimentation and the necessity for there being a drifting as well as a stationary body of sand in the filter. These would seem to be two great differences existing between modern mechanical plants of the gravity type, and the drifting sand gravity filter.

In the Toronto plant the water flows by gravity from the intake into a suction well, where the coagulant is introduced, the water being pumped directly to the filters.

Coagulation Plant.

The coagulation plant consists of a large storage bin in which is stored aluminium sulphate used for coagulation purposes. Through a number of control doors the chemical is automatically fed to two dissolving channels, the density of which is kept from 12 to 14 degrees Baumé (about 15 per cent. solution). The strong solution passes into a hydrometer chamber, where it is automatically diluted to the required strength. The hydrometer is poised in the solution between two valves, one discharging alum and the other water. Any vertical movement of the hydrometer opens one valve and closes the other. Thus the hydrometer tank is supplied with strong alum solution at the top, or water at the bottom, depending on whether the hydrometer is up or down. The tank is made of concrete, whilst the hydrometer is steel, thickly covered with paraffin wax, and has a displacement of 6 000 lb. of solution. It is weighted so as to just float in solutions of alum ranging between 4 per cent. and 10 per cent. Owing to the differences in the density of alum and water, circulation is maintained, a 10 per cent. solution of alum being approximately 5 per cent. heavier than water. The heavier liquid coming in at the top immediately starts traveling downwards and meets the lighter liquid rising upwards; at the point of discharge a perfect mixture is obtained, it being impossible to detect stratification. A beam with knife edges above the hydrometer, which is extremely sensitive, provides for permanent adjustment and also for altering the density of the solution. Along the beam is a scale of divisions graduated in one-tenth grains, so that by moving a weight the required strength of solution may be obtained. The solution of alum next discharges into an orifice chamber. A mechanical device regulates the discharge of solution which is proportionate to the quantity of water being pumped, this being indicated by a Venturi meter which is indirectly connected with the measuring slot. From the measuring tank the alum passes through a lead pipe to the suction well and is then pumped to the filters.

Pumping Station.

The lift of water from the well to the filters is 32 ft. The pumping station includes three electrically driven pumps with a combined capacity of 100 million gallons and a lift of 32 ft. Besides these, there are a two-million gallon auxiliary pump with 32-ft. lift, two half-million gallon backwash tank pumps with 100-ft. lift, two one-million gallon drainage pumps with 20-ft. lift and two hydraulic-pressure pumps, with a capacity of 8 640 gal. a day under 700 lb. per sq. in. The discharge of the main pumps is controlled automatically by the level of the water in the filter tanks, through pilot valves, operating hydraulic valves on the discharge of the pumps. There has also been installed a steam turbo-generator set, in case the electric power should fail.

Filters.

The multiple filter unit system was adopted in Toronto, and consists of ten units, each having a nominal capacity of 6 million gallons. Each filter is made of steel, is 14 ft. high, 50 ft. in diameter, and is divided into thirty smaller units. These units are nested together in two rings of 18 and 12 respectively. In the center of the filter is a space $16\frac{2}{3}$ ft. in diameter, in which is placed the raw water control balance. Each of the thirty units forms a separate quadrilateral unit with sand extractors, sand washer, and filtered water collecting system. For backwashing, an overflow channel 15 in. wide and approximately 3 ft. deep is placed round the outer ring. At the bottom of each filter, partly embedded in the concrete, is a cast-iron collector pipe for the filtered water. Running out from the collecting pipe are a series of $1\frac{1}{2}$-in. wrought-iron sherardized pipes, having $\frac{3}{8}$-in holes drilled on the underside, spaced about 6 in. apart. These pipes have a cap on the outer end and the inner end is screwed into the cast-iron collector. On the top of the pipes is rounded gravel in three grades, varying from $\frac{3}{4}$ in. to $\frac{3}{16}$ in. to a depth of 10 in., and above this is 9 ft. of sand. The total amount of sand in each filter is 600 cubic yards. No screens are used between the gravel and the sand. The sand has an average effective size of .375 mm., and a uniformity co-

efficient of from 1.6 to 2. Around each small unit is a system of slots, and the drifting sand is withdrawn from the filter by means of extractor pipes, through which the sand flows to the bottom of the filter unit into a sand washer. At the sand washer the sand falls to the bottom through a current of raw water and is thus cleaned. It is picked up by the incoming raw water and carried back to the filter. The dirty water impurities or suspended matter pass upward and out at the top of the sand washer by an outlet suitably controlled. A water jet is provided to assist the flow of sand through the extractor pipes, and, below the point of discharge, a glass inspection port is provided, so that the flow of sand from each extractor pipe can be observed. The sand washers are of cast iron. The throats are relined when occasion arises, with wrought-iron pipe liners, specially hardened by a carbonizing process. The liners are in three steps and are $13\frac{1}{2}$ in. high.

Operation.

The coagulant is introduced as the water goes direct to the filters, on the suction side of the pump. Owing to the operation of the drifting sand system, the sand contained in the filters resolves itself into two bodies — a stationary sand body supported by the gravel resting on the water collecting system and a drifting sand body lying between the surface of the stationary sand and the sides of the filter. By causing the sand to drift across the path of the raw water, a large proportion of the impurities, including the aluminium hydrate and the bacteria which have been caught up by the coagulant, is carried out along with a portion of the drifting sand. The stationary sand takes out the remaining impurities. The treated raw water enters the filter partly by a standpipe running through the center of the unit, which passes through a sand washer in the bottom, and delivers above the sand at the top of the pipe, and partly through a by-pass. Within the sand washer the raw water pipe is constructed similar to that of the tube of a Venturi meter and the drifting sand after being collected and washed in the sand washer is inducted into the raw water at the throat of the Venturi tube. This sand passes up the standpipe with the raw water and is delivered at the top of the filter. The

drifting sand forms a volcano-like cone that continuously drifts away and is being replaced with the washed sand from the sand washer, leaving a round top body of stationary sand below, resting upon the filtered water collecting system. The final purification is dependent on this body of stationary sand. The rate of flow of water passing through the by-pass may be varied in such a way as to suit the conditions of the raw water. In times of high turbidity the speed of the drifting sand is accelerated by decreasing the flow of raw water through the by-pass and increasing the flow through the standpipe. When in operation the stationary body of sand is found to be hard and compact with a cone-shaped-like surface, which is hard to penetrate. The drifting sand is of a buoyant and spongy nature and offers little resistance to penetration. In practice it is found that the slope of the drifting surface cone is a minimum of about 32 degrees and the slope on the surface of the cone forming the stationary sand is about 64 degrees.

Loss of Head.

The initial loss of head in the filters is 6 ft. and in the process of operation this gradually increases to 11 ft., when the filter is backwashed. Length of run of filters ranges between one and seven days according to the physical condition of the raw water and the amount of alum applied. Backwashing is accomplished by reversing the flow of filtered water through the bottom of the filter. The water is obtained from an elevated tank having a capacity of 200 000 gal. and which, on account of its elevation, supplies a natural head of 25 lb. Half the contents of the tank are passed through the filter at a gradually increasing rate, the first 100 000 gal. taking fifteen minutes, while the remaining quantity is passed through rapidly, the whole operation being completed in twenty minutes. The filter is then run to waste for twenty minutes, after which it is put into commission. The amount of dirty waste water passing through the sand washer is 2 per cent., while an additional 1 per cent. to 2 per cent. is used for backwashing and waste purposes.

Problems Encountered.

On a big plant embracing an entirely new system, it was expected that numerous problems would be encountered, particularly when the plant was put in commission, but with few exceptions, the difficulties have been overcome, and in no case can they be considered serious. In the early days, the biggest problem was to get a high-grade sand; about two thirds of the sand originally placed in the filters, amounting to over 4 000 cu. yd., had to be taken out and replaced at the expense of the contractors. At present the sand, while being satisfactory, is not quite uniform, having an effective size which varies between .35 and .4 mm. In the chemical house some inconvenience was caused by the corrosive action of the aluminium sulphate solution on the slotted trunk, through which the solution is discharged into the raw water. The trunk was made of vanadium silver, which has since been replaced by one made of pure copper. Tests are at present being conducted in the laboratory on a composition consisting of copper 92 parts and lead 8 parts containing 1 per cent. of antimony.

Sand Scour.

The question of sand scour has been the most troublesome. When the filters were first put in commission, the cast-iron throats did not wear as long as was expected, and they were relined, first with extra heavy black iron pipe and finally with similar pipe carbonized. Porcelain was tried but was unsuitable, and experiments with rubber are now under way. Most of the scour observed has been traced to a tail eddy, which forms at the back of the sand nozzle by the water passing it. By using the modified sand washer base the scour has been greatly reduced, and a number of new washers are being installed. Examination has shown that practically no scouring has occurred in the throat of the modified sand washer, after four months' continuous use.

Some trouble was caused in one filter by too rapid backwashing, which resulted in the disturbance of the gravel. The filter was emptied and the gravel replaced by 4 in. of 1 in. gravel and 6 in. of cemented gravel, in the proportion of 15 of gravel to 1 of cement.

The gravel used was the material which passed through a screen three meshes to the inch, and was retained on a screen having five meshes to the inch. This has proved to be very satisfactory.

Preliminary Experiments.

Prior to the completion of the new drifting sand plant at Toronto, extensive laboratory experiments were carried out over a period of eighteen months, the object being to collect as much data as possible that would likely be of value when the plant was put in commission. After six months' observation it became evident that the water of Lake Ontario was going to be an extremely difficult water to treat mechanically. That is to say, the purification effected after coagulation, under apparently the same physical conditions, varied from time to time. It was generally known that the quality of the water was governed by the meteorological conditions, which also controlled the temperature of the water. In the summer months, when the water was warm and the wind from an unfavorable direction, the water was invariably polluted. During the winter months the same unfavorable meteorological conditions produced a polluted water, which showed a drop in temperature instead of an increase, such as usually occurred in the summer months. This was explained by off-shore currents, which carried the shore water out, and at the same time met and mixed with the polluted water, which, in turn, was carried across the intake. For the laboratory experiments two small rapid sand filters were fixed up and sterilized. Raw water treated with amounts of aluminium sulphate, ranging between one half and three grains per Imperial gallon, was then passed through under varying conditions at the rate of 120 million Imperial gallons per acre per day. The removal of bacteria in the effluents was pro rata to the quantity of alum applied, the results being strikingly uniform. The time element was next studied, and the tests were made to determine what difference existed in the final purification between treated water after fifteen minutes' coagulation and after a period of three hours' coagulation and sedimentation. Little differences were noted, and the opinion was formed that the time element was not a factor in the resultant purification. Simi-

lar experiments were carried out in Ottawa with river water, by Joseph Race, city bacteriologist, and he found that the results between periods of two and one-half minutes and two hours were substantially the same. Tests were duplicated in the warm weather, and it was then noticed that the purification figures obtained under similar physical conditions in the summer months were considerably lower than were obtained in the winter months.

In 1918, when enough units of the new plant had been completed so as to allow testing to be carried out on a large scale, many of the observations proved of great value, and showed that the coagulation trouble that had been anticipated, actually worked out similarly to what occurred in the laboratory in the small experimental filters. Among other observations made were the resulting purification after coagulation and filtration of:

1. Lake Ontario water containing different degrees of turbidity.
2. Lake Ontario water free from pollution.
3. Lake Ontario water heavily polluted, winter conditions.
4. Lake Ontario water heavily polluted, summer conditions.
5. Temperature conditions of Lake Ontario water.

Turbidity did not help or hold up purification at any time of the year. The only effect was to cause an increased amount of alum to be applied at such times as was considered necessary for clarification purposes. Water free from pollution offered no difficulties. In the winter months a polluted water required at least one and one-half to two and one-half grains of alum in order to get a satisfactory effluent. During the summer months it was found necessary to apply at least two and one-half grains per Imperial gallon to a polluted water which was often free from turbidity. Water slightly polluted required about one grain per gallon. No satisfactory explanation of the varying conditions can be offered, although much experimental work has been carried out to determine what are the controlling influences. There is no doubt temperature conditions play an important part, although it has been generally conceded that warm water aided coagulation. In Toronto the raw water appeared to coagulate slightly better in the summer months when the water temperature exceeded 50 degrees Fahr., but the final purification effected was lower than in the winter period, when the water temperature ranged between 33 and

46 degrees Fahr. The microscopic content showed a great increase in the summer months, as also did the total number of bacteria present; these, again, might be a contributory cause. The most logical idea is that the colloidal content of the water in some months was largely responsible for the conditions noted, and that a direct relationship existed between the microscopical, bacteriological, and colloidal content. When the preliminary tests on the drifting sand experimental plant of one-half million gallon capacity were carried out in 1914 by Colonel Nasmith and Captain Adams, Humber Bay water was used (this was Lake Ontario water into which the Humber River flowed), and splendid efficiencies of over 98 per cent. were obtained on a test period of thirty-six consecutive days.

Purification Effected in 1918.

The appended tables show:

1. Average amount of water filtered; amount of aliminum sulphate applied; turbidity in raw and filtered waters.

2. Average number of bacteria per cubic centimeter growing on standard agar in twenty-four hours' incubation at 37 degrees C. in:

(*a*) Raw, filtered, and chlorinated water, together with percentage reduction in filtered and chlorinated water, all results included.

(*b*) Same as above, exclusive of three results for reasons specified.

3. Same figures, classified under summer and winter groupings.

4. Tests for typical *B. coli*, forty-eight hours at 37 to 39 degrees C., showing number of days present in raw, filtered, and chlorinated water. Indicated number of *B. coli* per 100 and 1 c.c. in the raw and filtered water, together with the total percentage reduction.

(*a*) All results included.

(*b*) Exclusive of three results for reasons specified.

With the object of showing the different degrees of purification effected in the two seasons of the year, two periods were grouped, the first being from December to May, and the second from June to November. The month of June produced a water that was easy to treat at all times, but for classification purposes was placed in the second period.

It has been previously mentioned that the raw water is subject to rapid changes. Frequently the water becomes heavily polluted after less than eight hours' change in the meteorological conditions. This makes the treatment exceedingly difficult, as occasionally a sudden polution has occurred and an insufficient quantity of alum applied, with the result that the efficiency of the plant has been impaired. Regarding the expression of results, inclusive and exclusive, it was felt that an explanation should be offered for same. The results excluded are, one in September and two in October, the reasons being that on two occasions abnormal pollutions occurred when the bacterial count in the raw water was in the neighborhood of 15 000 per cubic centimeter, and at the same time an insufficient quantity of coagulant (1.5 grains per gallon) was being applied. On the other occasion the alum was reduced too soon following a change in the direction of the wind. When chemical tests were made it was found that the water was still polluted, and consequently the alum was again increased. During the intervening period the sample was collected and proved to be unsatisfactory. As will be seen from the figures, the inclusion of these three results materially alters the average number of bacteria present, and also lowers the *colon* efficiency. It would seem to be scientifically incorrect to give only one set of figures, as a wrong impression might easily be formed.

The average number of bacteria per cubic centimeter growing on standard agar, 37 to 39 degrees C., was 369.5 in the raw and 53.4 in the filtered, inclusive of all results showing an average reduction of 85.4 per cent. Excluding three records for reasons previously specified, the figure was 303.6 in the raw and 34.7 in the filtered, with an average reduction of 88.4 per cent. The indicated number of *B. coli* per 100 and 1 c.c. was 612 and 6.12 in the raw and 31.70 and .317 respectively in the filtered, with a total average reduction of 94.8 per cent. If the three records before mentioned are excluded, the raw water would show 608 per 100 c.c. and 6.08 per 1 c.c., whilst the filtered water figure would be 22.0 per 100 c.c. and 0.22 per 1 c.c., with an average percentage reduction of 96.4. The chlorinated water showed an average bacterial count of 1.72 per cubic centimeter, while only two samples out of 1 900 samples examined showed the presence of *B. coli* in 1 c.c. This gives a total removal of 99.9 per cent.

Turbidity.

Particular attention has always been given to the clarification of the water, and it would be well to point out that the turbidity figures given are only those actually occurring at 9 A.M. daily. During the month of April the figure in the raw water ran up as high as 550 parts per million, and the maximum figure recorded in the table as occurring in the filtered water followed this high period of turbidity. The raw water figure given in the table as 160, was the degree of turbidity actually present in the raw water half an hour previous to the collection of the filtered water sample, this being the estimated time for the water to pass through the filter from the time the coagulant was first added.

Conclusions.

The original specifications called for certain efficiencies being obtained on an average amount of one grain per Imperial gallon of aluminium sulphate, this figure being largely based upon the results obtained on the experimental plant, on the Humber Bay water in Toronto. As a result of practical experience on the mechanical filtration of Lake Ontario water, considerable modification has had to be made as regards the operation of the new plant. Conclusive evidence has been forthcoming from experiments and borne out by actual results, that Lake Ontario water cannot be bacteriologically purified to a high degree by mechanical filtration, when only an average dose of aluminium sulphate of 1 grain per Imperial gallon is applied. The actual purification effected by the drifting sand filters, in 1918, was on an average application of 1.027 grains per Imperial gallon, and the results obtained on such a small amount are satisfactory. It has been clearly demonstrated (see diagram) that if a higher dose of alum was applied, a corresponding degree of purification was obtained. The economical question, however, had to be taken into consideration on account of the enormous cost of aluminium sulphate, and when it is considered that during periods of high pollution as much as 2.5 grains per gallon was applied, a definite economical as well as a practical policy of operation had to be adopted.

The summary of conclusions formed is as follows:

1. That Lake Ontario water can be treated effectively by mechanical filtration.

2. During the year the composition of the water appears to undergo two distinct changes, which make the treatment of the water difficult.

3. That in the summer months more coagulant is necessary than in the winter period.

4. That the purification effected by the drifting sand filters during 1918, upon an average dose of 1 grain per gallon of alum, was satisfactory.

Future Policy of Operation.

The plant is operated by the Department of Works, Commissioner R. C. Harris being the head of the department, with A. U. Sanderson as superintendent of the plant. The filtration laboratories, under the Department of Health, determine the amount of coagulant necessary. An excellent understanding has always existed between the two departments, and close coöperation on the plant has made its operation a simple matter. Our policy of operation as at present defined is:

1. Treat raw water at all times with sufficient aluminium sulphate to clarify the effluent effectively.

2. Obtain as high a bacterial efficiency as possible on an average dose of 1 grain per Imperial gallon.

3. Leave final sterilization to chlorine.

In conclusion, I would quote last paragraph from the official report on drifting sand filters, October, 1918, by Col. G. Nasmith and the writer, which reads as follows:

" The decision we arrived at when the tender for the mechanical plant was first let, ' That our former conception of a filtration plant was undergoing a material change; that sterilization of the water was the vital thing, from the public health standpoint, but that a filter was essential to clean the water, to keep the sand and dirt out of the water supply, and thereby prevent the wear and tear of machinery valves, taps, etc., as well as prepare the water for efficient sterilization; and that for a great portion of the year only a fraction of a grain of aluminium sulphate in conjunction

with a slight amount of chlorine would be essential for filtration, thereby resulting in a great saving in the cost of operating,' has been generally confirmed as a sound one, not only by ourselves, but by sanitarians in civilian and army work the world over." (See *Canadian Engineer*, issue of October 24, 1918, page 361.)

In connection with the preparation of this paper I am indebted to Col. Geo. Nasmith, director of laboratories; A. U. Sanderson, superintendent of the plant, and Messrs. Hannon and Thompson, of the filtration laboratory staff, for their advice and assistance.

TABLE 1.

DRIFTING SAND PLANT, 1918.

Table showing average amount of water filtered daily, together with monthly average of applied aluminium sulphate and turbidity in the raw and filtered water.

Month.	Av. Amt. of Water Filtered, Million Imperial Gallons.	Av. Amt. of Aluminium Sulphate Applied in Grains per Gallon.	Turbidity.					
			Raw Water.			Filtered Water.		
			Max.	Min.	Av.	Max.	Min.	Av.
January	30.95	0.98	80	1	6.2	under 1	under 1	under 1
February	33.16	0.65	24	1	3.9	under 1	under 1	under 1
March	33.63	0.92	54	1	12.7	3	under 1	under 1
April	32.49	1.48	160	1	27.9	18	1	2.4
May	32.74	1.04	7	1	2.1	under 1	under 1	under 1
June	31.76	0.82	2	1	1.3	under 1	under 1	under 1
July	39.13	0.61	3	1	1.5	1	under 1	under 1
August	38.00	1.08	10	1	1.8	1	under 1	under 1
September	36.9	1.02	25	1	2.8	under 1	under 1	under 1
October	40.61	1.2	4	1	1.4	under 1	under 1	under 1
November	44.19	1.07	35	1	2.9	under 1	under 1	under 1
December	37.7	1.3	75	1	21.3	under 1	under 1	under 1
Yearly average	36.0	1.027	..	.	....		under 1	

The average amount of chlorine applied to the water was .2 parts per million.

TABLE 2.

Average number of bacteria per cubic centimeter growing on standard agar 24 hours at 37 to 39 degrees C., in the raw, filtered, and chlorinated water, together with percentage reduction.

Month.	Raw Water.	Filtered Water.	Mixed Mechanical and Slow Sand Water Chlorinated.
January	42.2	3.3	1.2
February	7.4	1.2	1.0
March	43.0	3.2	1.6
April	73.4	5.6	1.0
May	28.7	5.7	1.1
June	108.5	11.4	2.8
July	97.1	19.9	1.4
August	653.0	67.3	2.4
September	738.7	82.5	1.4
October	1 382.5	29.1	2.5
November	779.8	78.1	2.7
December	534.4	33.3	1.4
Yearly average	369.5	53.4	1.72

Per Cent. Purification Effected in Agar.

A. — Average of 303 samples. Average of 1 900 samples.

Raw water.	Filtered water.	Chlorinated water.
369.5	53.4	1.72

Total average reduction.

In filtered water.....85.4% In chlorinated water.....99.5%

B. — Same, exclusive of three results for reasons specified.

Raw water.....303.6% Filtered water.....34.7%

Total average reduction, 88.4%.

TABLE 3.

Showing the variation that occurs in the efficiencies in the winter and summer month periods.

Average Number of Bacteria per c.c. in the Raw and Filtered Water with Percentage Reduction.			*B. Coli Test.* Showing Number of Days that *B. coli* was present in Raw and Filtered Water with Percentage Reduction.										
WINTER PERIOD.													
Month.	Raw Water.	Filtered Water.	Raw Water.						Filtered Water.				
			100	10	1	0.1	0.01	0.001	100	10	1	0.1	0.01
December	534.39	33.35	25	23	18	11	5	1	25	16	9	1	0
January	42.23	3.31	22	11	8	1	0	0	13	7	0	0	0
February	7.42	1.21	24	15	2	1	0	0	22	8	2	0	0
March	42.98	3.24	23	17	7	3	0	0	19	10	3	0	0
April	73.44	5.62	24	19	13	6	0	0	23	10	6	0	0
May	28.73	5.62	25	15	5	0	0	0	24	13	2	0	0
Removal, 92.8%.			Total removal, 97.8%.										
SUMMER PERIOD.													
June	108.54	11.38	21	14	2	1	0	0	18	4	0	0	0
July	97.08	19.92	22	14	4	1	0	0	24	14	3	0	0
August	653.2	67.31	26	24	15	4	0	0	26	23	9	0	0
September	738.6	128.80	24	19	11	5	0	0	24	16	10	0	0
October	1 382.46	290.5	26	21	15	9	0	0	26	18	7	2	0
November	779.6	33.32	24	13	7	1	0	0	25	19	7	0	0
Removal, 84.1%.			Total removal, 75.8%.										

TABLE 4.

Tests for typical *B. coli* 48 hours at 37 to 39 degrees C., showing number of days present in the raw and filtered water, and chlorinated water. Indicated number of *B. coli* per 100 and 1 c.c. in the raw and filtered water, together with the total percentage reduction. A. — All results included. B. — Exclusive of three results for reasons specified.

Month.	Raw Water.						Number of Samples.	Filtered Water.					Chlorinated	
													Number of Samples Positive.	Percentage of Samples Negative.
	100	10	1	0.1	0.01	0.001		100	10	1	0.1	0.01	1 c.c.	.1 c.c.
January	22	11	8	1	0	0	26	13	7	0	0	0	0	100
February	24	15	2	1	0	0	24	22	8	2	0	0	0	100
March	23	17	7	3	0	0	25	19	10	3	0	0	0	100
April	24	19	13	6	0	0	25	23	10	6	0	0	0	100
May	25	15	5	0	0	0	26	24	13	2	0	0	0	100
June	21	14	2	1	0	0	24	18	4	0	0	0	1	99.4
July	22	14	4	1	0	0	26	24	14	3	0	0	0	100
August	26	24	15	4	0	0	26	26	23	9	0	0	1	99.4
September	24	19	11	5	0	0	24	24	16	10	0	0	0	100
October	26	21	15	9	0	0	26	26	18	7	2	0	0	100
November	24	13	7	1	0	0	26	25	19	7	0	0	0	100
December	25	23	18	11	5	1	25	25	16	9	1	0	0	100
Totals	286	205	107	43	5	1	303	269	158	58	3	0	2	99.9

A. — Indicated number of *B. coli* per c.c. —
Raw water per 100 c.c., 612 — Filtered water per 100 c.c., 31.70
Raw water per 1 c.c., 6.12 — Filtered water per 1 c.c., 0.317
Total reduction inclusive of all results, 94.8%.
Chlorinated water, 99.9%.

B. — Raw water per 100 c.c., 608 — Filtered water per 100 c.c., 22.0
Raw water per 1 c.c., 6.08 — Filtered water per 1 c.c., .22
Total reduction exclusive of three results for reasons specified, 96.0%.

Discussion.

Mr. Frank W. Green.* I should like to ask if, when you have a longer coagulation, it does not reduce the wash water, and also if it would not be better, considering it was made of steel and iron, to have as units the squares or rectangles, and also why the sand depth has to be so great.

Mr. Howard. Regarding the first question, it possibly would affect the loss of head, but we have found that the units go sufficiently long so that we do not have to bother about that. We get a normal run of anything up to ten days, with a minimum of one day, under very bad conditions. We get severe storms occasionally on the lake, in which large quantities of sand, not so much turbidity as large quantities of very fine sand, are thrown up, and there is a tendency to clog the filters. That sand is thrown out by the drifting sand process.

As regards the round filter units, that was simply a matter of design. The round unit design was accepted by the city. I believe in other places square units have been adopted, and I think that probably in the future they will be used wherever this system is adopted.

As regards the depth of sand, this is necessary because a minimum depth of permanent sand must be maintained at the point where the drifting sand passes into the extractor system. There is a depth of 26 in. at this point and there are 10 extractor pipes for each unit. The extractor pipes surround the unit and there are 30 units to each filter. It was considered absolutely necessary to have a minimum depth of permanent sand. It is obvious that if the whole body of sand was moving it would be impossible to get any purification at all. The final purification is entirely dependent upon this permanent body of sand.

Mr. G. A. Sampson. What is the total construction cost?

Mr. Howard. $1 096 000. That was the lowest tender by $100 000. We had another one of $1 177 000; the next one was $1 197 000; and the last one was an English tender of $1 750 000, about $650 000 higher than anybody else on this side of the pond.

* Superintendent of Filtration, Montclair, N. J., Water Co.

Raw water ... Total reduction exclusive of three results for reasons specified, 99.0%.

That actually was the last tender. Undoubtedly the prices had a bearing on the awarding of the contract.

MR. JAMES M. CAIRD.* During the time you had a low temperature of water and clearer water, I understand you to say that your period of coagulation was about twenty-five minutes?

MR. HOWARD. Actually about fifteen minutes. It takes eight minutes to pass through the filter.

MR. CAIRD. Did you have any trouble with alum passing the filter at that time?

MR. HOWARD. We got a slight trace of aluminium hydrate. It is almost invisible. We run a daily test not only on the mixed effluent but on every unit. There is a slight trace of aluminium hydrate in the filtered water. There are mighty few mechanical plants of any type using aluminium sulphate where you will not get a trace of the aluminium hydrate. We experimented by passing the filtered water through very fine filter papers and found that the hydrate was not decreased in any way.

MR. CAIRD. Doesn't that seem to tend to coagulation somewhere in the distribution system and cause some troubles around the distribution system in getting a mass of that out at times?

MR. HOWARD. We have taken water containing what we considered a little more than the average, when we have had a high dose of alum in, — 2½ grains. There was an increase of the aluminium hydrate in the effluent: it was at all times small, but it was there. We took the water and allowed it to stand under varying conditions to see what the result would be, and found that it disappeared after standing twenty-four hours.

MR. THEODORE HORTON.† Do you have any trouble in the distribution system from corrosion due to the passing through of alum?

MR. HOWARD. No, none at all. The plant has been in service now since about November, 1917, and we have not noticed any increase; in fact, we have had no complaints anywhere.

MR. GREEN. What is your carbonic acid?

MR. HOWARD. It depends upon how you estimate that. If you take standard methods, — that is to say, the standard methods

* Bacteriologist and Chemist, Troy, N. Y.
† Chief Engineer, New York State Department of Health.

of the American Public Health Association, — testing with phenolphthalein, we get a reaction indicating that there is no CO_2 present at all; if we take our laboratory methods, in the presence of sodium chloride, we find that the water contains 3 parts per million of carbonic acid gas. That is actually increased in the effluent to about 4½ parts per million.

MR. CAIRD. Are you having any boiler troubles?

MR. HOWARD. The boiler troubles occurred in the early days of operation, but were overcome. We have had leakage trouble around the stays of the boilers. This was said in the beginning to be due to the boilers getting steam up too rapidly. When the power fails, the steam system is used. There have been times when the power failed for twenty-four hours. Originally, when talking about the hydroelectric power system, we were told that the power could not fail. The engineer said the power would never fail but for a few minutes at a time; and within a month it was off twenty-four hours. Our trouble was mainly attributed to too rapid firing of the boilers. It takes two hours, I think, to get up full steam; but our generator can be put in commission in half an hour.

MR. M. N. BAKER.* Will you please tell us what expert advice the city relied on before launching upon this rather bold experiment?

MR. HOWARD. The city, as you are probably aware, had a very able engineer as consulting expert, and he, at the time, recommended slow sand filtration. The city did not act upon his report but relied on their own authorities to guide them in their system. No consulting engineer advised on this at all. They took their own engineers, the heads of the laboratory division, and after running a test advised the acceptance of this system.

MR. BAKER. Wasn't it based very largely upon the advice of the medical officer of health?

MR. HOWARD. In all instances he had to O.K. the recommendations. The medical officer of health, representing the Health Department, O.K.'d the work of Colonel Nasmith, the head of the laboratory division, who conducted all the experiments. When the latter reported upon this matter, it had to go to the head of the department for approbation.

* Associate Editor, *Engineering News-Record*, New York.

MR. BAKER. Do I understand it was done on his recommendation?

MR. HOWARD. It was on the direct recommendation of the city engineer and endorsed by the medical officer of health. The contractors were always governed, and the city protected, by a clause in the specifications, which said that the water purification should be based upon one grain of alum under average conditions. There is no doubt but what under average conditions the water is perfectly well purified, using one grain or less of alum.

MR. GREEN. How many days do you treat on one grain or less?

MR. HOWARD. I think approximately at least two hundred days in the year.

MR. GREEN. What is the average?

MR. HOWARD. 1.027 grains. That is a point to consider in this paper, — that for the year 1918 we probably could have gotten higher efficiencies if we had wanted to. We demonstrated that clearly. But we were more or less tied to the grain per gallon, because at that time alum was costing us $93 a ton in Toronto, and we were using 8 tons a day. If you consider the amount of $700 or $800 for coagulation alone, you can see it was a very serious proposition.

MR. CAIRD. I understand you to make the statement that my experience does not bear out directly; that is, the fact that all plants that use sulphate of aluminium get alum in the filtered water. Now, I have had experience with a few plants, and if a plant is properly operated there would be no sulphate of aluminium or aluminium hydrate in the filtered water. I only have in mind one plant where I had any trouble with aluminium hydrate in the filtered water. In all the other plants there was no aluminium hydrate in the filtered water. Every test showed it to be absolutely free. And the statement that all these plants have aluminium hydrate is pretty broad.

MR. HOWARD. I do not say all plants; I say, mighty few plants do not get a reaction; I base that opinion upon statements of many sanitarians who have visited Toronto, and I have very carefully asked them if they ever had any trouble. Some of them said they had none at all, others have said it depended upon how much alum they applied. That condition applies absolutely to Toronto.

With a small amount of alum we get no aluminium hydrate; when we start climbing up we get a reaction.

MR. CAIRD. Isn't there a low point where you will get aluminium hydrate, when you put alum in the water and it refuses to coagulate?

MR. HOWARD. We have not found that. We have never found aluminium sulphate in the filtered water. If we did we would consider it a serious question.

MR. W. C. HAWLEY.* I should like to say for our plant, which has been operating for over nine years, that we have never had aluminium hydrate in the filtered water until some time in the last six weeks, when somebody dumped a tank of acid in the Allegheny River. That was caught within half an hour, probably. But in the early days of mechanical filtration one of the chief objections, especially on the part of physicians, was that the alum would go through, and would have a serious effect upon the interior mechanism of all those who used the water. It is not many years ago since a very determined effort was made in the legislature of the state of Pennsylvania to prevent the use of alum, and the idea of the man who presented that measure was that the alum was going through the water and the people would suffer. But through the efforts of Mr. Caird the legislation was killed.

MR. HOWARD. I take it that you are only referring to the hydrate; you are not referring to the sulphate, which would be a serious thing. I would agree with you if you said that the sulphate would be harmful to the intestinal tract. We have never had a trace of sulphate; I am only talking about the aluminium hydrate.

MR. GREEN. I should like to say that I have known of hydrate of lime at Little Falls, and of other cases of that kind. I should like to ask the last gentleman if he ever got hydrate of aluminium.

MR. HAWLEY. I do not think I ever did. We have not had any report on it.

MR. HOWARD. It is a good thing that this point was mentioned, because originally we were led to believe that there would not be any. While we got practically none, there is undoubtedly a trace, and when we got that in the first instance, got in touch

* Chief Engineer and General Superintendent, Pennsylvania Water Co.

with several people. Their replies led us to believe that it was quite a common thing and occurred on many mechanical plants.

MR. GREEN. I think in most cases it only lasts for a brief time and has no serious result. But I think in most plants where there are frequent tests made, there are occasions when there are slight traces.

MR. WILLIAM J. ORCHARD.* Will you discuss some of the savings which have been effected in reducing the amount of coagulant required by adding chlorine before the alum?

MR. HOWARD. We considered if we could get rid of what little suspended matter was present by the filters, without alum or by reducing the alum to a minimum quantity, and then sterilize the effluent with chlorine, we would be doing a good thing from a public health and also from an operating standpoint. The point involved from an operating point of view was that our loss of head would undoubtedly have been reduced, and we would have required less backwashing. We tried a Wallace & Tiernan installation out for about a week, and got excellent results. I might say that we picked a week when the water was very good to do this, and we proposed trying out waters of varying qualities before we definitely laid down our policy as to how we were going to operate. At the end of the first week we got practically sterile results in 100 c.c. By that time we were ready to go ahead with the chlorination plant, it having been previously erected on the assumption that we were to reduce the cost of chemicals by about $20 000 a year. We figured on saving in the neighborhood of 200 to 300 tons a year. At the price it was then, it amounted to $20 000. The water was also chlorinated as it was pumped at the other end of the tunnel, leading to the city. The medical officer of health refused to have the water chlorinated at both ends, for the simple reason that he felt sure there would be a taste in the water. Unfortunately for us, when we were at the end of our first week, the weather suddenly changed, and we got a susceptible water, in which a perceptible taste of chlorine occurred. Occasionally we get this condition in Toronto, but so far we have been unable to determine what is the cause. In this particular instance it was said to be due to the added amount of chlorine we were putting in at the filtration plant,

* With Wallace & Tiernan, New York.

although we were actually only applying .125 parts per million, which we considered insufficient to cause any taste. Nevertheless, these two conditions happened at the same time, and we were held responsible. The medical officer of health had not been aware of the new chlorine installation at the plant, and immediately gave instructions that it was to be cut out. In spite of many efforts made on our part to put this plant in commission again, we have been unsuccessful. The plant, in future, will be held in reserve and we will have to get along the best we can. We had certainly figured on a saving up to $20 000 per year in our operation when we installed it. Of course the public is an important factor to consider, particularly when a taste occurs in the water. We had so much experience in Toronto along that line before the filtration plants were put in operation that everything must be done to avoid a repetition of the prefiltration conditions.

MR. PAUL LANHAM.* I should like to ask what advantage is claimed for the drifting sand filter over the ordinary mechanical filters.

MR. HOWARD. We do away largely with sedimentation. The total area of this plant, which is capable of filtering 70 million gallons, is $1\frac{1}{4}$ acres. If the coagulation basins had been put in, it would have taken very much more land. In Toronto it might not have made much difference because the land was cheap and belonged to the city. In other cities, where the land has to be bought, the interest charge on capital for the necessary amount of ground, would make a considerable difference in the cost of operation of the plant.

MR. MORRIS KNOWLES.† I am sure we shall study this over with a great deal of interest as we read it in print. Many of us have been interested to know how this plant was received in the long run. It is rather an interesting bit of history to me that should not go unnoticed, that many scores of years ago filtration was used in Great Britain. In the latter part of the nineteenth century it was used on this continent, but lately a filtration development called the "American" or "mechanical" has gone on apace

* Engineer in charge of Waste Prevention, Washington, D. C.

† Director, Department of Sanitary Engineering, University of Pittsburg, Pa.; Consulting Engineer.

and has very much advanced. Now we find our English brethren are modifying the American form and introducing a system which perhaps, after all, will make some revolutionary changes in the art. I am sure we can all study with a great deal of profit these new things, because it is by such advancements that we may promote the cause of better water.

There are two things that occur to me that I shall be pleased if Mr. Howard will answer. I do not understand if the Toronto water is severely polluted or highly turbid, as we know some of our waters of the West and South are. Have any experiments ever been made with that character of water which would indicate how such a filter would act? Then again, have any experiments been made with another coagulant — namely, iron and lime — so as to indicate what could be accomplished under such conditions?

MR. HOWARD. Regarding the first question, when the experimental plant was put up, river water was used and clay mixed with it; a turbidity of 880 parts per million was produced. That was passed through the filter with excellent results, the figures being in the official report. The Toronto water generally is highly polluted, and at times has high turbidity. We actually found in running the plant on a big scale that we required at least 3 grains per gallon to deal with a turbidity of 550 parts per million which occurred last spring. That turbidity consisted largely of clay, washed off the cliffs some five miles east of the plant.

We found one condition in this plant which it is necessary to catch in its inception. If we allowed the turbidity to get a hold in the filter without a sufficient quantity of alum, we would get turbidity in our effluent. In the month of April you will see in the tables there was a turbidity actually reported in the effluent of 18. That was the resulting turbidity from the night before. For a period of twenty-four hours it exceeded 500 parts per million, although the table only shows 160. The direction of the wind changed during the night, and when the morning samples were collected the raw water had gone back to 160 and a residual turbidity of 18 in the effluent. Possibly had one of us been on the plant at night — and we certainly will be in future — we should have added from 3 to $3\frac{1}{2}$ grains of alum, which would have probably prevented the turbidity in the effluent.

As to the second point, — the use of iron sulphate was tried as a coagulant in the laboratory extensively, with the idea of applying it instead of aluminium sulphate. Our principal reason for discontinuing its use was that, so far as I remember, it caused a dirty deposit in the mixing tanks, and we thought it would be undesirable to pass it on to the filters. We tried another series of laboratory experiments, working with several kinds of chemicals, and made observations on the coagulation produced by aluminium sulphate in the presence of peptones, gelatines, and other ingredients. True, we had differences. In the summer period we were somewhat puzzled to explain the results, which we thought might possibly be due to the content of the gelatinous films which formed on the slow sand filters. We thought that some condition might be occurring in our mechanical plant which was interfering actually with the coagulant. For that resaon we added .1 part per million of gelatine to the water and then added the alum and found that it completely held up coagulation. It was instructive but did not convey anything new to us, and did not really explain what was the different condition occurring in the summer months.

Mr. Caird. Did I understand that you washed those filters once a week under good conditions, and your wash water was two per cent.?

Mr. Howard. Yes; dirty water, two per cent.; wash water, one to two per cent.

Mr. Caird. When it came to washing every day under your extremely turbid conditions, what did the wash water amount to?

Mr. Howard. A little over 4½ per cent. is the highest we ever had. We accelerated the flow of the drifting sand, and that helped us out quite a lot. By drifting the sand faster, the filters lasted longer. If each filter was backwashed once a day it would involve about 2 million gallons of backwash water being used. You can figure out the percentage. That is an extreme condition which would be more or less balanced by the small amount of water used during other periods of the year. For instance, we have had some units go ten days; we make a practice now of not letting them go over six days.

Col. Francis F. Longley.* I think the members of the Asso-

* Consulting Engineer, New York.

ciation have to thank Mr. Howard very sincerely for his extremely interesting presentation of this new and novel development of filtration. There is one point, however, on which little or no information has been given, and I think Mr. Howard has made a brief statement upon it which would be interesting to members of the Association. That is as to the relative costs of construction and the relative costs of operation of the two plants that are now operated side by side on the Island at Toronto.

MR. HOWARD. While there are no figures available as to cost of operation, the cost would be about two to one. The mechanical plant costs twice the amount to operate that the slow sand costs. This would not be based upon the same amount of water, the slow sand plant would be filtering 32 000 000 and the mechanical about 36 000 000 million gallons. Actually, the question of chemicals is the big factor. I would not want to state this figure as an absolute one, but it is roughly in the neighborhood of two to one. The slow sand plant cost approximately $775 000, while the mechanical plant cost $1 096 000.

MR. W. N. BAKER. Before this discussion closes I think it is only fitting that some tribute should be paid to the great ingenuity that was shown by the engineers who designed this plant for the contractors. As far as I remember, the paper did not give the name of the engineer. It was Mr. William Gore, was it not?

MR. HOWARD. Yes.

MR. BAKER. Mr. Gore, who is, I think, a member of the Institute of Civil Engineers, and who, I understand, was associated at one time with Mr. Deacon of Liverpool, the famous water engineer we have heard of in connection with the Deacon waste-water meters.

Another tribute should be paid to the people who were willing, as the contractors were, to risk such a vast amount of money on a process involving radical changes, although at this time I understand plants of large capacity were built at Kingston, Jamaica, and one or two other points, in England, yet it was risking a very large amount of money on a very radical process and going back to the first principles, you might say, as to the elimination of a period of free coagulation.

Those of us who are old enough to remember the court contest

which took place between the mechanical filter companies, when they were fighting themselves to death, about twenty-five years ago, will remember that that was one of the points of contention; things were fought out in court on the patent, and that question as to the necessity of a period of coagulation before the water went through the filters was one of the points in issue. We eliminated that and also saw a tremendously high rate of filtration. Now we should all look forward to the developments on the drifting sand filter, and as to what the cost will really turn out to be when those figures are available.

I should like to say one thing further, which applies to the position a great many cities find themselves in, and the risk that some of them seem quite willing to take in connection with new and relatively untried processes. There have been a number of cities in this country that now have suffered very materially in this way. It is an experiment, and when a new process for sewage treatment has gone far enough so that the city is warranted in putting in its money to try out that system, notwithstanding the fact that some contractors, some capitalists, are willing to come forward and put up the money, the city is nevertheless taking a great risk whenever it does anything of this sort, because if it needs a filter plant it needs it; it does not want to run the risk of having a very large and expensive plant built, litigation ensue, a long period pass by, and then find itself, as New Orleans in the early history of mechanical filtration found itself, without a filtration plant — a very remarkable and interesting case, a thing which at last contributed very materially to the ruin of the water company there and the final taking over of the plant of the water company by the city, the city building a rival plant, as you might say, and the company only getting a small amount of money for, as I understand it, a certain amount of main that was in the street.

Now, it is getting very late, but there is just one other thing I should like to speak of on this line, and that is, the intensely interesting feature of this is the drifting sand and the principle of mechanical agitation in connection with the treatment of water and sewage, — a thing which I think might well be investigated further than it has been. We have had it in Massachusetts.

There is a certain parallel which might be drawn between this

treatment of water and the treatment of sewage which has been recently experimented on in eastern Pennsylvania and elsewhere. We have there mechanical agitation and the lime treatment and electrolysis combined.

I think there is a very great deal in connection with this drifting sand process that certainly would repay thorough study. At the same time, I must agree that Toronto took a tremendous risk in building a plant of that size, practically without any engineering advice, as I understand it, at all, and I hope it will turn out that it was warranted in doing so and that the process will fulfill the expectations of the city in promoting it.

MR. CHARLES W. SHERMAN.* Before we adjourn I think we want to express our appreciation of Mr. Howard's courtesy in coming here and giving us this very interesting information, which so many of us have been anxious to obtain for some time.

MR. GEORGE A. JOHNSON (*by letter*).† The writer is particularly interested in Mr. Howard's paper for a variety of reasons. In the first place, the process is a radical departure from long-established practices in water purification; and, second, the drifting sand filter plant at Toronto has ever been enveloped in a fog of uncertainty respecting its cost of operation and practical performances.

In the winter of 1913–14, the writer was preparing a monograph for the American Water Works Association, entitled, "Present-Day Water-Filtration Practice," and learning of the probable decision on the part of the Toronto authorities to adopt the Ver Mehr drifting sand system in the proposed 60 000 000 gal. (Imp.) extension to the existing slow sand system at that place, sought to obtain reliable information about it, that he might refer to it in his then forthcoming article on water-filtration matters in general. He learned that Sir Alexander Binnie was alleged to be an advocate of the process, and as the time was short before his article went to press he cabled Sir Alexander for a statement regarding it. Sir Alexander replied that the only plant of this type he had seen was a small installation in Wales, but that he was impressed by it and thought highly of its possibilities.

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* Of Metcalf & Eddy, Boston, Mass.

† Colonel, U.S.A., Utilities Division, Construction Division of the Army.

Correspondence with certain public officials in Toronto, and even personal inquiry on the ground, developed only the same line of indefinite information.

Prior to May, 1913, a test plant having a daily capacity of 500 000 (Imp.) gal. was installed by the Ver Mehr Company near the old West Toronto pumping station, and on May 21, 1913, turned over to the city authorities for official test.* This test was run between the dates of May 21, 1913, and June 27, 1913, and upon the results then obtained, and the recommendations of Dr. Nasmith, the Ver Mehr Company was permitted to put in a bid for the 60 000 000 gal. (Imp.) installation. Of the four bids tendered, the Ver Mehr bid was $1 096 000, as against the other three of $1 177 000, $1 197 000, and $1 750 000, respectively, and the contract went to the low bidder.

From the time the test plant was installed in May, 1913, until the present day, the writer has endeavored to obtain information relative to the cost of operation and maintenance of the new filtration works, but his efforts have thus far been without definite result. The 1915 article by Dr. Nasmith was scrutinized in vain for light on this important point, and it is with regret that even at this late date Mr. Howard seems unable to give the profession any information on this vital phase of the matter. In reply to a question by Colonel Longley, he sweepingly dismisses the subject with the reply that "there are no figures available as to cost of operation." Personally, the writer does not see how any discussion of the merits of the drifting sand filter can be of definite utility until some one is ambitious enough to relate the whole story and advise the public, not what this plant cost to build, as compared with what either a slow sand or the established type of rapid sand system might have cost, — even going so far as to grant that all three would produce an equally satisfactory effluent, — but what are the actual costs of operation and maintenance.

A somewhat mysterious phase in operating results is described by Mr. Howard in reply to a question by Mr. Caird relative to whether alum passes the filter. Mr. Howard states that "there

* The results of this test were reported out by George C. Nasmith and F. Adams, of the Department of Public Health, Toronto, in an article which appeared in *Engineering Record*, April 10, 1915.

is a slight trace of aluminium hydrate in the filtered water." Further on, he says, "We experimented by passing the filtered water through very fine filter papers, and found that the hydrate was not decreased in any way." Now, this is suggestive. All water-filtration men know that where aluminium hydrate is in suspension in water, that hydrate, no matter how finely divided the particles may be, can be removed by passage through fine filter paper; that is, if the texture is fine enough and there are enough thicknesses of the paper. If the resulting filtrate then reacts alum, the presence of undecomposed alum is proved, and not aluminium hydrate. All this suggests that as a sequence of a practically negligible period of coagulation in this process undecomposed alum may be passing the filters, later perhaps to become decomposed and form an undesirable deposit in the pipes, or to cloud the filtered water as it leaves the taps in the city. If not so decomposed, an active corrosive agent is thus present in the filter effluent. This point requires clearing up by Mr. Howard in his closing discussion.

From the information before him, the writer is not prepared to accept without question the Toronto drifting sand filter as a reliably efficient and economical process of water purification. It is ingenious and seems to satisfy the Toronto authorities; but it is not apparent that the citizens of Toronto desire the drifting sand process at any cost, and it seems quite unusual that a plant which has been operated as long as has this one should not have developed accurate costs, a statement of which the profession at large, and the taxpayers of Toronto assuredly, would appear to be justly entitled to. When these figures are published it is to be hoped that they will be so decisive as to set at rest, once and for all, the doubt now existing in the minds of a great many water-works engineers as to whether Toronto is actually receiving acceptable water purification service at reasonable cost.

TESTS OF THE UNAFLOW PUMPING ENGINE.

BY D. A. DECROW, OF WORTHINGTON PUMP AND MACHINERY CORPORATION, NEW YORK.

[*Read October 3, 1919.*]

The members of the New England Waterworks Association may not all have had opportunity to become familiar with the principle of the Unaflow steam engine, which is not particularly new though its successful development as a practical and economic commercial machine is quite recent.

It derives its name from the fact that the steam entering the cylinder travels through the cylinder in one direction. Its development in this country has been very greatly retarded during the past two or three years by stress of war work which crowded it one side, but it is now being actively taken up and developed by a number of steam engine builders.

Generally speaking, the principle of the Unaflow reciprocating steam engine is that of utilizing the heat energy of the steam in the cylinder during the period of its admission, expansion, and flow in one direction, the expanded steam being released or exhausted through ports or openings uncovered by the travel of the cylinder piston at that period of its stroke most remote from the point of admission. A typical Unaflow steam cylinder and a typical set of indicator cards from a condensing engine are here shown. (Fig. 1.)

Typical Unaflow Steam Cylinder and Indicator Cards.

The piston is at one end of the stroke with the exhaust ports uncovered. The arrow indicates the path of the steam through the cylinder. The steam enters the cylinder at one end and there is practically no change of temperature until the point of cut-off is reached. After cut-off, expansion takes place with a consequent

drop in temperature, and at this time condensation begins, due to the changing of heat into work. As the cylinder head is jacketed with high steam, no condensation takes place on the walls of the head; the condensation is on the wall of the piston, which is comparatively cool so that at the end of the stroke when the piston uncovers the exhaust ports the moisture of condensation is mostly at the exhaust end of the cylinder and as the steam expanding away from the cylinder head rushes out through the exhaust port

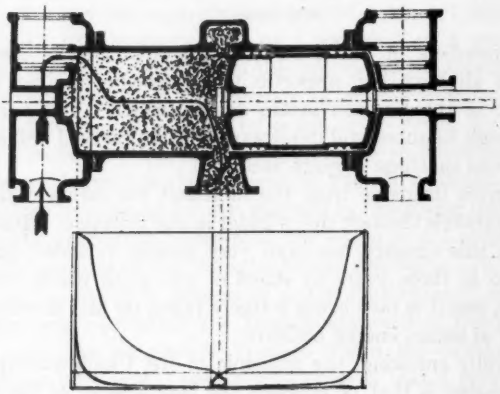


FIG. 1. TYPICAL UNAFLOW STEAM CYLINDER AND INDICATOR CARDS.

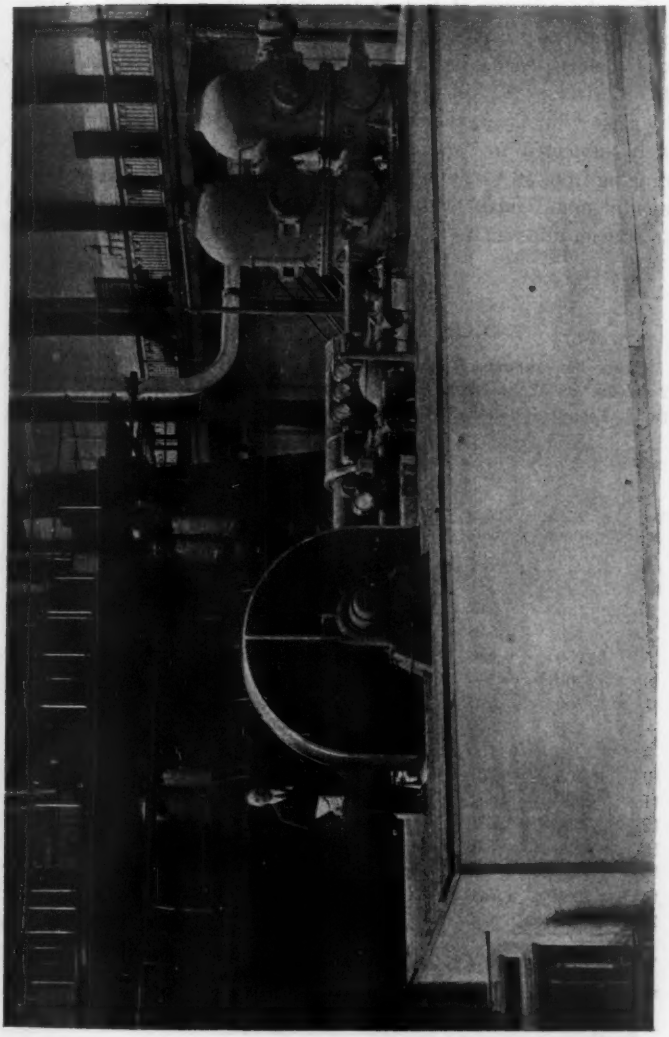
it takes the moisture with it. At this time there is a sudden drop in temperature in the cylinder, due to the sudden drop of pressure, but as the inlet end of the cylinder is dry it does not lose its temperature materially. The flow of heat from a dry surface being slow there is not time for any perceptible drop of temperature on these dry walls. The exhaust port is covered by the piston on the return stroke, trapping in the cylinder comparatively dry steam partially superheated. As the walls of the cylinder have retained their heat, the heat of compression is not absorbed either by moisture or by cold walls as in the case of the counterflow engine, and the steam remaining in the clearance is heated by compression to a temperature above the temperature of the initial steam; when the valve is opened to start the next stroke, the live steam

rushes into the clearance space in which the steam entrapped is hotter than the entering steam, hence no initial condensation. Owing to the removal of practically all of the moisture of each stroke, the well-known heat losses caused by the presence of water in counterflow engines are avoided.

It is also evident that leakage losses at the exhaust valves in the counterflow engines are eliminated. The absence of initial condensation permits a high economic ratio of expansion in one cylinder. There apparently is no particular gain in economy in compounding this type of engine.

Taking into consideration its simplicity and economy, the Unaflow engine seems to be a distinct step in advance of other types of reciprocating steam engines. Its advantageous features have attracted attention to it as a motive power for reciprocating pumping engines, and one of our pumping engine manufacturers has designed, constructed, and operated in the Porter Avenue Waterworks Pumping Station of the city of Buffalo a complete Unaflow high-duty condensing pumping engine of about 3 000 000 gal. daily capacity. This engine is of the horizontal type, having one steam cylinder and one double-acting plunger pump. It was designed for the following normal working conditions: Water pressure 100 lb. per sq. in.; suction lift, 15 ft. plus the friction in about 60 ft. of suction pipe; steam pressure, 235 lb. per sq. in., 100° F. superheat. It is shown in the foreground of this interior view of the Porter Avenue Station, five 30 000 000 gal. vertical triple expansion pumping engines forming the background, and in the two closer views following.

At the time consideration was given to the adaptation of the Unaflow steam engine to pumping practice it became apparent that in order to take advantage of its most economic speeds a marked improvement in pump valve and pump construction would be necessary, the basic feature of which was to develop a pump valve that would operate satisfactorily under all the varying conditions of speed and pressures to which pumping engines are liable to be subjected, and a valve was designed and constructed that seems to fulfill all of these requirements. It is shown with the flow of water through this type of valve compared with the flow of water through an ordinary standard pump valve.



For the purpose of testing this valve under various working conditions, a special power pump driven by a variable speed motor was constructed having a single acting plunger 2 in. diameter by 12 in. stroke. In this pump the pump valves were surrounded by glass cylinders so their operation could be readily observed, and were subjected to various tests, the pump being run at speeds ranging from 50 to 290 r.p.m. The maximum lift of these experimental pump valves was $\frac{3}{16}$ in. This pump valve was subjected to sixteen different tests for slippage, with the following results.

BUFFALO, N. Y., October 31, 1918.

EXPERIMENTAL HIGH-SPEED PUMP.

Tests for slippage. Water pressure, 35 lb. Plunger, single acting, 2 in. dia. by 12 in. stroke. Theoretical displacement, 1.361 lb. per revolution. Tests 1 to 9 made October 26; 10 to 16, October 30.

Test No.	Speed R.P.M.	Total Revs.	Plunger Displacement, Lb.	Total Lb. of Water Weighed.	Slip plus or minus.	Average Velocity through Valves, Feet per Second.
1	75	519	706.36	709	−4/10 of 1%	1.52
2	60	534	726.77	727		1.54
3	125	543	739.02	739		3.2
4	150	540	734.94	735		3.84
5	150	560	762.16	761	+2/10 of 1%	3.84
6	200	560	762.16	764	−2/10 of 1%	5.12
7	200	530	721.33	723	−2/10 of 1%	5.12
8	250	549	747.19	745	+3/10 of 1%	6.4
9	250	550	748.55	746	+4/10 of 1%	6.4
10	200	537	730.86	733	−3/10 of 1%	5.12
11	200	510	694.11	696	−3/10 of 1%	5.12
12	290	470	639.67	645	−8/10 of 1%	7.42
13	290	530	721.33	727	−8/10 of 1%	7.42
14	290	490	666.89	671	−6/10 of 1%	7.42
15	250	550	748.55	748	+1/10 of 1%	6.4
16	250	530	721.33	722	−1/10 of 1%	6.4

NOTE. Plus slip indicates that plunger displacement is more than actual water pumped.

Minus slip indicates that plunger displacement is less than actual water pumped.

The scales for weighing the water were tested and found to be correct.

When operating at 290 r.p.m. the valve opened $\frac{3}{16}$ in., the amount of opening was determined from the sound of the valve disk tapping the valve guard. At all other speeds the valves were noiseless in operation. These tests were very carefully conducted.

In developing a pump end the "unaflow" principle, in so far as it would apply to a pump, was given due consideration. This pump cylinder is of the general design shown by Fig. 1.

The tests of the 3 000 000 gal. pumping unit above described have been delayed and are not entirely completed. The working conditions for which the engine was designed have not yet been obtainable. For instance, instead of 100 degrees superheat steam it has been found that less than one tenth of this superheat was actually available, and no tests have yet been made with steam superheated to any extent. An independent superheater has been secured and is now being installed which will permit the making of tests with varying degrees of superheat, from 10° to 200° F.

One test for steam consumption has been completed, with approximately 200 lb. steam pressure, 95 lb. water pressure, 10 degrees superheat, 27.2 in. vacuum, 203 r.p.m., the resultant steam consumption per indicated horse-power hour being approximately 12.4 lb. as compared with 11.9 lb. of steam per indicated horse-power hour that the perfect Unaflow steam engine with 27 in. vacuum is supposed to develop under these conditions; the resultant duty was something under 140 000 000 foot-pounds.

A short slip test with calibrated nozzles was made at speeds ranging from 100 to 202 r.p.m., the percentage of slip decreasing at a uniform rate as the speed of the pump increased so that the apparent per cent. of slip at 200 r.p.m. was less than two thirds of the apparent slip at 100 r.p.m.

Both of these tests were made hurriedly in the endeavor to secure the data to present at this meeting. The results given are substantially correct; but further tests are being made and shortly we expect to know exactly what may be expected from this type of engine as to economy and general efficiency, under various conditions of service.

DISCUSSION.

MR. HARRY GARDNER. Did you say that no higher efficiency has been developed than in the ordinary engine?

MR. DECROW. When we built this first engine, as far as the steam end was concerned we had to accept the contention of the licensees as to the economy of steam consumption. We are working now to find out what it is. They claim under the conditions we have operated that with a perfect Unaflow Engine we should get 11.9 lb. of steam per indicated horse power per hour, or with 235 lb. of steam and 100 degrees superheat the engine should give an indicated horse power per hour with 10 lb. of steam. We have obtained 95½ per cent. of the licensee's claim on the first trial. We are now trying to see if we cannot get it closer. It takes time, however, to do these things.

MR. A. P. FOLWELL. Did you state what the slip was?

MR. DECROW. There has been only one test for slippage made on this particular machine, and the water was measured by calibrated nozzles furnished by the New England Underwriters Association. I assume the figures were substantially correct. They showed about 4 per cent. slip; but we expect to reduce this to less than 1 per cent.

MR. WILLIAM F. SULLIVAN. In a general way, as a general proposition, what is the prospect of saving on this type of engine, and also of general use?

MR. DECROW. It is going to cost considerably less than the cross compound, and we expect about the same or better results. There will not be any particular saving in the pump end because for a given quantity it has to have so much water passage anyway, but on the steam end we expect to save a good deal. I would say that the probable cost of it would be about 70 per cent. of the cost of a cross compound of the same capacity.

MR. EDWARD D. ELDREDGE. Do you attach considerable importance to the discharge of the moisture in the cylinder into the exhaust at the end of the stroke?

MR. DECROW. Oh, yes. We used to have reheaters in the receivers between the steam cylinders of our compound and vertical triple expansion engines, to re-evaporate any moisture, but

we found from actual experience that they were a detriment rather than a benefit, on the general theory, I presume, that no conversion is 100 per cent. perfect or 100 per cent. efficient. We do get rid, however, of any moisture formed as soon as possible.

MR. CHARLES W. SHERMAN. I should like to inquire about the room taken up by this machine.

MR. DECROW. That measures about 30 ft. long, and it is about 4 ft. wide, except at the flywheel.

MR. SHERMAN. You compared it in efficiency with the compound. Is it less in space occupied?

MR. DECROW. In space?

MR. SHERMAN. Yes. How does it compare?

MR. DECROW. The three million horizontal cross compound would probably be 12 ft. wide.

MR. SHERMAN. About the same length?

MR. DECROW. Well, it would be about 27 or 28 ft. long.

MR. SHERMAN. I presume it requires a flywheel?

MR. DECROW. Yes. The flywheel and moving parts are cased in. We did that on the general principle that if you are riding in an automobile you do not care what speed the engine is running at as long as it runs all right and you do not see or hear it. Water-works men, particularly the older engineers, do not care to see things run very fast.

MR. ELDREDGE. Do the piston rings pass the ports properly?

MR. DECROW. Yes. There is no trouble with that at all. The ports are circular holes around the cylinder.

THE SUPERVISION OF PUBLIC WATER SUPPLIES BY THE NEW YORK STATE DEPARTMENT OF HEALTH.

BY THEODORE HORTON, CHIEF ENGINEER.

The supervision of public water supplies by state boards and departments of health is, quite naturally, somewhat limited in scope though very important in character. It is limited in scope for the reason that the engineering and laboratory divisions of these health departments, whose resources are dependent upon legislative appropriations, have many functions to perform besides those relating to public water supplies. It is important in character because it is life saving in its purpose; and we must all concede that no purpose could be of much greater importance.

The authority which is exercised by the various states over public water supplies varies considerably. In some states this authority is lodged almost exclusively in the state board or department of health, which has supervision over questions not only of sanitary quality, but of yield, capacity, and distribution. In other states this authority is shared, through a somewhat sharp division of powers and duties, with some other state department, such as a water supply commission, or a conservation commission.

In the state of New York the supervision over public water supplies is exercised jointly by the state Department of Health and the state Conservation Commission. Although these two departments have, by statute, powers which somewhat overlap, in practice they work in close coöperation, and by mutual recognition each department performs separate and independent functions. The Health Department limits its jurisdiction and activities almost exclusively to engineering and laboratory questions pertaining to the sanitary quality of water supplies. The Conservation Commission limits *its* jurisdiction almost exclusively to legal and engineering questions of yield and distribution, including the

examination of plans for water-supply systems, authorization of bond issues, and the granting of permits for the use of the waters of the state for water-supply purposes. It is the supervision of the sanitary quality of these supplies to which the speaker will confine his remarks, for it is this work which the Engineering Division of the state Department of Health has been engaged in, during the past thirteen years.

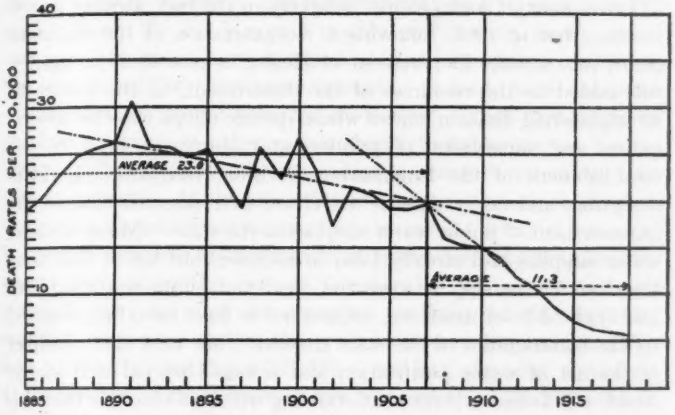
The Engineering Division was established in 1906, soon after the old state Board of Health was reorganized into a state Department of Health, with some five divisions or bureaus, of which the Engineering Division is one. When first established, the division staff comprised the chief engineer, one full-time assistant engineer, one part-time assistant engineer, and one part-time stenographer. The chief engineer's office was a corner of the health commissioner's conference table, when that was not in use. To-day, the regular divisional staff consists of twelve full-time engineers and five stenographers, with additional part-time employees for special investigation work. Incidentally, it should be kept in mind, the Engineering Division has many other duties besides those relating to water supplies, including examination and approval of plans for sewerage and sewage disposal, the abatement of important nuisances, supervision of milk pasteurization, and investigation and advice relating to stream pollution, garbage disposal, drainage, and other sanitary subjects. The work in connection with water supplies is, however, considered the most important, and approximately one half of the engineering force is employed almost exclusively upon it.

Before describing the character of our work in connection with water supplies, I wish to present a chart showing the typhoid fever rate in the state for the past thirty-five years. As you all know, the typhoid fever rate is one of the best indices of the sanitary conditions of any locality, and this curve for the state of New York is both interesting and instructive to those interested in epidemiology — particularly in relation to public water supplies. The chart is almost self-explanatory in regard to its construction; that is, abcissæ represent years from 1885 to 1918 inclusive, and ordinates the typhoid fever death rates, per hundred thousand of population. A glance at the chart shows that it may be divided

into two general periods, one prior to about 1907, and the other subsequent thereto. The characteristics of the earlier period are:

1. The rates for nearly the entire period are excessive, averaging approximately 23.1.

2. There is a marked lack of uniformity, the curve ascending and descending with considerable irregularity.



TYPHOID FEVER DEATH RATES IN NEW YORK STATE SINCE 1885
NEW YORK STATE DEPARTMENT OF HEALTH

THEODORE HORTON
Chief Engineer

3. The range of deviation from the mean is excessive, the curve ascending to a point above 30, in one instance, and below 18, in another.

In contrast with this part of the curve, note the character of the curve for the second period subsequent to 1907, and you will observe:

1. The rates are moderate, averaging for the entire period 11.3, and reaching the low point of 5.4 at the end of the period in 1918.

2. The curve is uniform in character, progressively descending, with only slight deviation at any point from the general direction.

3. The yearly rate of change at the latter end of this period is very much less than the rate of change at the beginning of the period; indicating that the limit of reduction of mortality from typhoid fever in the state has begun to be reached.

Now the question which naturally arises, after glancing over this curve is: What influence or changes in condition began to be exerted at the beginning of the later period, ranging from 1906 to 1919, that might rationally account for the subsequent rapid and uniformly downward trend of this curve, and the comparatively very low rate reached in the year 1918?

The answer, it seems to me, is largely in the fact, already stated to you, that in 1906, following a reorganization of the old state board into a state Department of Health, a new force or agency was added to the resources of the department, in the nature of an engineering division, one of whose specific duties was the investigation and supervision of public water supplies. Prior to the establishment of the Engineering Division, comparatively little attention, and no systematic activities, were directed toward the improvement of public water supplies in the state. Many of these water supplies had already been introduced, but up to that time the close relationship between the quality of public water supplies and typhoid fever incidence, seemed not to have been fully realized by the communities of this state generally, nor were the principles of the art of water purification and sewage disposal well understood. This fact is somewhat startling when we consider that this knowledge and relationship were well recognized by sanitarians, and by some state health authorities, as for instance in Massachusetts, where public water supplies were under excellent supervision, and were generally of good quality, and where the typhoid fever rate in the state was much lower than in this state. It is of particular interest to note, however, that almost simultaneously with this extension of the organization and scope of the New York State Department of Health at this time, and especially the establishment of the Engineering Division, equipped with scientific knowledge and facilities for systematically studying and investigating public water supplies, we find a very marked increase in public interest concerning the sanitary quality of public water supplies. This was clearly evidenced by a general demand for investigations; by a pronounced willingness by municipalities to heed advice; and by an almost immediate decline in the typhoid fever rates throughout the state — a decline that has uninterruptedly continued up to the present time.

Very naturally one may inquire at this point as to how we know that this decrease in typhoid fever is due to water-borne infection and not to other causes. No better answer can perhaps be given than by referring you to the accompanying table, showing what has actually occurred in the cities of the state with reference to typhoid fever, as a result of introducing water purification plants and other sanitary improvements. The table explains itself; and if you will glance down the list you will readily see that, in nearly every instance, the rates have dropped almost immediately following the introduction of these improvements. It is of course conceded — and the fact should never be overlooked — that typhoid fever is often traceable to other causes than infected water, as, for instance, infected foods, fly transmission, contact infection, and disease carriers. At the same time we must not overlook the fact that when typhoid fever occurs from so-called "residual" causes, it appears generally in the nature of epidemics, readily traceable, except perhaps in the case of "carriers." Nor again must we overlook that in most communities, at least in this latitude, supplied with *pure* water, the typhoid fever rates are generally low, and rarely over 10 per 100 000 — and less, of course, according to the freedom of these communities from infection due to so-called "residual causes." When, then, we are considering persistent and uniformly high rates, as 30, or 50, or even 100 per 100 000, as in the case of Niagara Falls and Albany, before these water supplies were improved, we can feel reasonably certain that we are dealing almost entirely with water-borne typhoid.

Finally, one has only to glance at such a table as this to be convinced that by no possible coincidence could any other reason than the purification or other improvement of the water supply be responsible for the marked reductions in the typhoid fever rates of these cities. In fact, out of the entire list there are only a few cities where it may be said that an improvement in the quality of the water supply has *not* been followed by a marked lowering in the typhoid fever rate. In these few cases either the original rates were not excessive before the introduction of water purification or the absence of the lowering of the typhoid rate has been due to special reasons, such as to inefficient operation of purification plants or to epidemics due to other causes, such as milk infection, typhoid carriers, etc.

Beginning with the year 1906, the Engineering Division started a series of special investigations of certain public water supplies, selected with special reference to high incidence of typhoid fever. A year or two later these special investigations were made a part of the routine work of the division, The yearly returns from this work, in terms of lowered typhoid fever rates, so clearly demonstrated its value that in each succeeding year more attention was given to this part of our work. It remained, however, for our present commissioner, Dr. Hermann M. Biggs, to fully appreciate the great value of this sort of life-saving work, and to foresee in it a great opportunity for lowering the general death rate of the state. In fact, almost immediately upon assuming office, Dr. Biggs directed that the principal work of the Engineering Division should be the investigation and supervision of public water supplies, and that this work should be prosecuted until all of the water supplies in the state shall have been investigated and improved, and the mortality rate from this source reduced to a minimum. It is needless to say that this policy is still in force; and the present low typhoid rate indicates that these aims of our commissioner have already been largely realized.

Although the speaker hesitates to burden you with statistical information, he wishes to state briefly, however, a few figures showing the progress that has been made during the past twelve years in the development and improvement of public water supplies in the state. In 1906 there were, in round numbers, some 400 public water supplies in the state, serving a population of about 6 100 000 persons. Of these supplies about 50, serving a population of 700 000, received some sort of treatment, either by slow sand or mechanical filtration. In 1919 there are approximately 530 public water supplies in the state, serving a population of approximately 8 500 000. Of these supplies about 130, serving a population of approximately 6 900 000, are treated either by filtration or chlorination. This means that in the thirteen years, from 1906 to 1919, the number of people supplied with public water supplies had increased from 6 100 000 to 8 500 000, or approximately 40 per cent.; while in the same period the number of people protected by water purification, in some form, had increased from 700 000 to 6 900 000, or an increase of almost 1 000 per cent.

Time will not permit of entering into *much* detail as to the methods employed in the supervision of these 530 supplies. The nature of our work is, of course, based primarily upon the provisions of the public health law. These provisions specifically authorize the state commissioner of health to enact and enforce rules and regulations for the protection of the watersheds of these supplies, and, generally, authorize him to investigate and report upon all of the water supplies of the state. At the present time about 80 out of the 330 surface water supplies of the state are protected by rules and regulations. Generally speaking, these rules and regulations are in the nature of prohibitions or restrictions against the pollution of reservoirs and water courses from various sources of polluting materials, such as privies, cesspools, sewers, barnyards, etc. These sets of rules and regulations are individual in character, vary with the different municipalities, and are enacted only after a careful inspection has been made of the watershed, and the specific requirements in each case determined. The enforcement of the rules involves action by the state and local authorities having jurisdiction. The procedure for abatement of violations is somewhat long, if not cumbersome, being designed to carefully protect riparian rights, and requiring that the *expense* of abatement shall be met by the municipality owning the supply — incidentally, a provision which has from a legal standpoint been the subject of much controversy.

It is the general investigations of the water supplies of the state, however, toward which the activities of the Engineering Division have been principally directed, for it is through these investigations and the advice and recommendations based upon them, that the most effective results have been accomplished. In an investigation of this kind, an assistant engineer is usually assigned to make a field inspection, which includes a sanitary survey of the watershed furnishing the source of supply, and an inspection of such physical features as pumping stations, distributing reservoirs, filter plants, etc. During this field inspection, statistical information is also obtained of the history and development of the water system, and of certain engineering data such as yields, capacities, storage, water consumption, and operating rates of pumps and filters. Bacteriological and chemical samples of

water are also collected of the source or sources of supply, of the raw and filtered water, in case of purification plants, and at such other points as may be necessary, — these samples being sent to the Division of Laboratories at Albany for analysis. Upon the completion of the field inspection a careful study is made in the office of the results obtained in the field, and of the laboratory analyses.

These studies are finally incorporated into a full report which has three essential features: first, a description of the physical character of the sources and distribution works; second, a discussion of the sanitary condition of the watershed, and the sanitary quality of the water; and third, our conclusions and recommendations, based upon the results of our studies. This report is duly transmitted to the local water board or company, the local board of health, and the sanitary supervisor of the district, who coöperate in the final part of the program, namely, a follow-up campaign for the purpose of stimulating public sentiment and the interest of the local authorities in having the recommendations in the report carried out.

Practically all of the 530 public water supplies in the state have been thus fully investigated and reported upon, and a large majority of them reinvestigated one or more times. The information contained in these reports is, of course, a great asset to the department, and particularly to the Engineering Division; for these reports form a complete system of records which are valuable not only for comparative future studies, but as a basis for concentration of efforts upon those supplies where improvements are needed.

As a part of the records kept of these supplies I should perhaps mention the application of the scoring system which has been developed by the writer and one of his assistant engineers, Mr. E. S. Chase. This system was carefully described in a paper presented to the Sanitary Engineering Section of the American Public Health Association in 1916. The score is on the percentage basis, and involves a combination of factors including the sanitary conditions on the watershed, the extent of water purification, and the efficacy of the measures of prevention and correction of pollution as indicated by laboratory analyses. Such a score system is valu-

City and Population. (State Census of 1915.)	Source of Water Supply.	Present Treatment.	Remarks.
Albany 107 979	Hudson River	Prefilters, slow sand filters, and sterilization.	Sand filters installed 1899. Prefilte pochlorite plant installed 1909.
Amsterdam* 34 319	Hans Creek and Steele Creek with large reservoirs.	No treatment	Progressive improvement, two s abandoned, 1910.
Auburn* 32 468	Owasco Lake	Sterilization	Hypochlorite apparatus installed treatment since 1913.
Batavia* 13 278	Tonawanda Creek	Mechanical gravity filters and sterilization.	Filters and liquid chlorine installed
Beacon* 10 825	Surface streams. Auxiliary supply from Fishkill Creek.	Auxiliary supply sterilized when used.	Liquid chlorine plant installed in 19
Binghamton 53 668	Susquehanna River	Mechanical gravity filters, sterilisation.	Filters installed in 1902, hypochlorit
Buffalo 454 630	Lake Erie	Sterilization	Liquid chlorine plant installed 1913.
Canandaigua 7 501	Canandaigua Lake	No treatment	
Cohoes* 23 433	Mohawk River	Mechanical gravity filters and sterilization.	Filters and hypochlorite apparatus i
Corning* 13 459	Dug well	Sterilization	Liquid chlorine plant installed 1915.
Cortland* 12 367	Dug well	No treatment	Gradual improvements to protect w
Dunkirk* 17 870	Lake Erie	Sterilization	Liquid chlorine plant installed May,
Elmira* 40 073	Chemung River	Mechanical gravity filters and sterilization.	Filtered since 1896. Hypochlorite u
Fulton* 11 138	Dug wells	No treatment	Gradual improvements to elimina Oswego River water.
Geneva* 13 232	Seneca Lake	Slow sand filters	Filters installed 1914.
Glens Falls 16 323	Surface streams and storage reservoir.	No treatment	Rules and regulations enacted 1912.
Gloversville* 21 178	Surface streams and storage reservoirs.	Sterilization apparatus to be installed.	More effective patrol since 1912.
Hornell* 14 352	Seeley Creek	Mechanical pressure filters and sterilization.	Filters installed in 1899. Water sup Liquid chlorine plant installed 191
Hudson 11 544	Taghkanic Creek and Churchtown Reservoir.	Slow sand filters	Filters installed in 1874. Hudson R 1905. Liquid chlorine 1914.
Ithaca* 16 750	Six Mile Creek	Mechanical gravity filters and sterilization.	Filters installed in 1903 following typ chlorite used since 1914.
Jamestown 37 780	Driven wells	No treatment	
Johnstown* 10 688	Surface streams	Sterilization	Liquid chlorine installed 1918.
Kingston* 26 354	Sawkill Creek	Mechanical pressure filters and sterilization.	Filters installed in 1898. Hypochlo 1912.
Lackawanna* 15 737	Lake Erie	Sterilization	Liquid chlorine plant installed in 191
Little Falls* 13 022	Surface streams	Slow sand filter for portion of supply. Sterilization.	Liquid chlorine plant installed in 191
Lockport* 18 693	Niagara River	Sterilization	Source changed in 1909 from Erie ca Liquid chlorine plant installed 191
Mechanicville 8 208	Surface streams	Supply partly filtered in slow sand filter.	Filter installed in 1909.
Middletown 17 381	Surface streams	Mechanical gravity and pressure filters.	Filters installed in 1900.
Mt. Vernon* 37 583	Surface streams	Slow sand and mechanical pressure filters and sterilization.	Filters installed 1894. Hypochlorit Mamaroneck River source. Liq cently installed.
Newburgh 27 876	Silver Creek and Washington Lake.	Sterilization	Hypochlorite used since 1914. Liqui
New Rochelle* 31 758	Surface streams and driven wells.	Sterilization	Hypochlorite used since 1913.
New York City 5 468 190 (est.)	Croton River, Bronx River, Byram River, surface streams, and driven wells.	Sterilization	Hypochlorite plant installed in Cr Liquid chlorine treatment used sinc
Niagara Falls* 42 257	Niagara River	Mechanical gravity filters and sterilization.	Water company supply and municipa 1912. Water company supply pa 1912. Hypochlorite treatment o Liquid chlorine treatment of wate each case since 1912.
North Tonawanda* 13 498	Niagara River	Sterilization	Liquid chlorine plant installed Nov., 1
Norwich 8 342	Chenango Lake and surface streams.	Mechanical pressure filters and sterilization.	Filters installed in 1905. Hypochl later.
Ogdensburg* 14 338	St. Lawrence River	Slow sand filters	Filters installed in 1913 and source gatchie River.
Olean* 17 925	Driven wells and Olean Creek.	Sterilization (wells). Gravity mechanical filters and sterilization.	Liquid chlorine for wells 1918. Oles used 1919.
Oneida 9 461	Surface stream	No treatment	
Oneonta* 10 474	Oneonta Creek	Mechanical pressure filters and sterilization.	Filters installed since 1906. Hypochl
Oswego* 25 426	Lake Ontario	Sterilization	Oswego River source abandoned for I Hypochlorite treatment. Liquid ch
Plattsburg* 10 134	West Brook and Reservoirs	Sterilization	Hypochlorite plant installed in 1915. 1916.
Port Jervis* 9 413	Surface ponds and streams supplemented by Neversink River.	Sterilization of Neversink River supply when used.	Hypochlorite treatment of Neversink used, since 1914 and liquid chlorine
Poughkeepsie* 32 714	Hudson River	Slow sand filters and sterilization.	Filters installed in 1872; improved plant installed 1910. Liquid chl 1913.
Rensselaer 11 210	Hudson River	Mechanical gravity filters and sterilization.	Filters installed 1901. Hypochlorite Liquid chlorine 1917.
Rochester 248 465	Hemlock and Canadice Lakes	Sterilization for Canadice Lake only.	Canadice Lake first used 1919.
Rome* 21 926	Fish Creek	Sterilization	Source changed from Mohawk River t Liquid chlorine installed in 1916.
Salamanca 8 370	Springs and driven wells	No treatment	
Saratoga Springs* 13 792	Loughberry Lake	Sterilization	Liquid chlorine installed 1919. More 1914.
Schenectady 80 381	Large wells intercepting ground water flow to river.	No treatment	Use of Mohawk River water discontin
Syracuse 145 293	Skaneateles Lake	Sterilization	Liquid chlorine installed 1917. Since tected by revised rules more rigidly
Tonawanda* 9 147	Niagara River	Sterilization	Liquid chlorine plant installed August,
Troy 75 488	Surface streams and lakes	No treatment	Partial use of Hudson River water disc
Utica* 80 589	West Canada Creek and small surface streams.	West Canada Creek water sterilized since 1914.	Since 1906 watershed protected by rigidly enforced.
Watertown* 26 895	Black River	Mechanical gravity filters and sterilization.	Filters installed 1904 following typhoi chlorite used since 1911.
Watervliet* 14 990	Normanskill	Mechanical gravity filters and sterilization.	Source of supply changed to Normansk
White Plains 19 287	Driven wells, dug wells, and surface stream.	No treatment	Polluted wells abandoned and watersh 1912.
Yonkers 90 913	Saw Mill, Sprain, and Grassy Sprain Rivers.	Slow sand filters and sterilization for Saw Mill River Supply.	Two slow sand filter units installed in plant installed in 1910. Two ad installed in 1909 and two in 1915.

* Improvements in the public water supply made following investigations a

ANNUAL TYPHOID FEVER DEATH RATES PER 100 000 POPULATI

1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	18	94.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.
19.0	20.4	22.7	24.9	25.6	26.1	30.5	25.8	25.7	24	.7	25.4	22.6	19.4	25.6	22.4	26.7	25.4	17.4	21.5

Typhoid fever death rate per 100 000 population in the cities of the state (con

	Typhoid Fever Death Rates. (Average annual deaths per 100 000 population.)					
	Before Improvement in Water Supply.	After Improvement in Water Supply.	1901–5.	1906–10.	1911–15.	1916–18.
ilters installed 1908. Hy-	1889–1890	1900–1918				
	88.8	18.7	21.8	17.0	18.3	10.2
small polluted streams	1898–1910	1911–1918				
	28.4	8.0	23.8	14.9	11.0	2.9
d 1911. Liquid chlorine	1898–1910	1911–1918				
	20.3	14.1	20.6	18.2	14.3	14.0
ed 1917.	1898–1916	1917–1918				
	30.1	21.2	36.9	31.0	16.5	13.4
1914.	1913–1914	1915–1918				
	0.0	4.8	.....	.....	20.2	3.1
orite.	1889–1902	1903–1918				
	50.3	11.6	22.2	13.6	12.0	8.5
913.....	1901–1913	1914–1918				
	24.1	11.2	29.2	23.3	15.6	9.7
.....	.....	.....	34.4	38.5	21.7	22.0
us installed in 1911.....	1888–1911	1912–1918				
	84.8	19.9	88.9	71.4	45.8	8.6
915.....	1898–1915	1916–1918				
	42.7	32.3	38.4	52.2	25.4	32.3
t well.....	.....	.....	32.4	28.6	18.5	9.8
lay, 1914.....	1898–1914	1915–1918				
	34.5	9.8	43.7	29.7	31.8	7.5
te used since 1911.....	1888–1896 1897–1910	1911–1918				
	53.8 39.2	12.7	45.1	32.8	12.1	13.7
inate surface water and	.....	.....	37.3	17.6	25.2	14.6
.....	1898–1913	1914–1918				
	31.3	17.8	36.4	20.1	31.2	17.2
912.....	.....	.....	35.0	30.8	17.5	13.9
.....	.....	.....	18.5	13.6	10.3	3.1
supply rules enacted 1913.	1890–1899	1900–1918				
1915.	55.0	17.3	31.6	17.4	10.0	2.3
n River source abandoned	1898–1904	1905–1918				
	78.6	25.4	73.8	25.4	28.5	17.3
typhoid epidemic. Hypo-	1898–1903	1903–1915				
	78.4	17.3	90.1	15.2	23.1	11.6
.....	.....	.....	27.9	23.1	14.3	5.0
.....	.....	.....	12.1	10.2	7.5	0.0
chlorite plant installed in	1898–1911	1912–1918				
	19.6	21.7	18.2	23.1	19.9	26.5
1913.....	1909–1913	1914–1918				
	4.3	3.9	.....	.....	5.0	2.1
1916.....	1898–1916	1917–1918				
	26.4	30.0	26.0	19.2	17.2	22.5
e canal to Niagara River.	1898–1908	1909–1913 1914–1918				
1913.	57.2	33.2 19.9	53.8	47.8	33.1	28.1
.....	1901–1909	1910–1918				
	19.9	15.7	29.6	12.3	7.9	24.0
.....	1894–1900	1901–1918				
	31.0	24.1	26.2	24.8	28.5	11.9
orite used since 1909 for	1898–1908	1909–1918				
Liquid chlorine plant re-	14.7	8.2	14.3	16.2	8.9	6.8
Liquid chlorine since 1916.	1898–1913	1914–1918				
	38.4	17.1	36.9	41.8	29.6	16.7
.....	1898–1913	1914–1918				
	16.6	4.9	24.9	20.1	6.8	3.0
Croton aqueduct 1912.	1901–1912	1913–1918				
since 1916.	15.1	5.6	18.1	14.0	8.1	4.3
icipal supply filtered since	1898–1911	1912–1918				
y partly filtered prior to	128.4	19.8	145.1	108.1	60.4	8.0
nt of municipal supply.						
water company supply in						
v., 1914. Poorly operated.	1898–1914	1915–1918				
	36.8	27.0	32.1	43.7	45.2	26.1
ochlorite plant installed	1901–1905	1906–1918				
	11.9	7.6	11.9	0.0	17.5	3.8
urce changed from Oswe-	1898–1912	1913–1918				
	50.0	17.8	55.5	41.1	23.4	19.1
Olean Creek supply first	.....	.....	20.4	14.5	11.2	3.4
.....	.....	.....	20.0	15.9	7.1	6.8
ochlorite treatment 1914.	1899–1906	1907–1918				
	35.8	28.0	36.3	48.2	19.4	15.5
for Lake Ontario in 1910.	1898–1910	1911–1918				
id chlorine since 1917.	45.4	14.3	48.0	53.6	17.5	9.0
15. Liquid chlorine since	1898–1915	1916–1918				
	25.6	34.5	21.1	21.9	37.1	34.5
rsink River water, when	1898–1913	1914–1918				
rine since 1916.	36.1	8.0	60.4	33.3	21.0	3.6
ved 1907. Hypochlorite	1898–1907	1908–1909 1910–1918				
chlorine plant installed	45.2	28.7 11.9	41.7	45.3	13.1	7.7
rite plant installed 1911.	1898–1901	1902–1910 1911–1918				
	102.6	46.1 6.8	62.3	33.0	7.4	5.9
	.....	.....	13.6	13.0	9.5	3.3
ver to Fish Creek in 1909.	1898–1909	1910–1915 1916–1918				
6.	23.0	16.8 13.3	24.6	21.4	16.3	13.3
.....	.....	.....	12.4	27.0	9.8	10.9
More effective patrol since	.....	.....	40.1	23.3	30.1	18.7
ntinued 1903.....	1890–1903	1904–1918				
	86.0	9.5	26.2	11.0	8.1	5.2
Since 1906 watershed pro-	1898–1906	1907–1916 1917–1918				
idly enforced.	19.7	13.9 8.7	14.4	14.9	12.2	10.1
gust, 1919.....	.....	.....	23.3	46.9	30.5	14.1
r discontinued 1906.....	1898–1906	1907–1918				
	55.7	24.1	45.7	27.7	23.1	23.9
l by revised rules more	1898–1906	1907–1914 1915–1918				
	18.2	11.6 9.0	16.0	17.1	7.8	10.9
yphoid epidemic. Hypo-	1898–1904	1905–1911 1912–1918				
	94.9	46.5 16.1	81.2	50.9	18.1	19.8
nanskill 1918.....	1898–1917	1918				
	43.7	20.1	56.6	32.5	49.8	20.1
atershed improved about	.....	.....	9.5	14.9	14.6	1.6
d in 1904. Hypochlorite	1898–1904	1905–1909 1910–1918				
o additional filter units	11.8	7.2 8.0	11.2	10.6	8.5	3.5
15. Liquid chlorine 1917.						

tions and recommendations of the department.

ULATION IN NEW YORK STATE, 1885–1915.

1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.
21.5	20.9	19.2	19.0	19.8	16.0	15.1	15.0	14.0	11.8	10.5	8.8	7.7	5.9	5.7	5.4

te (combined population, 8 234 738) for 1918=5.1.

able for comparative purposes, stimulates a rivalry among municipalities for improvements, and enables the division to know at a glance which are the good, the bad, and the indifferent supplies, — incidentally which ones should be the subject of our attack for the purpose of improvement.

In addition to these investigations and other routine duties connected with water supplies, there are, as might be assumed, other phases of the work of a special or miscellaneous nature. One of these is the preliminary advice and final approval of water supplies of various state institutions and county tuberculosis hospitals, of which there are more than 100, some with populations of 5 000 or over. Another is the investigation of water supplies of private institutions and individuals where for special reasons these are authorized. Still another, and perhaps one of particular importance, is the emergency disinfection of a supply when it has been deemed to be the source of an impending or actual epidemic of typhoid fever. This last phase of the work has been carefully developed and has been found to be highly effective. The Engineering Division maintains an emergency chlorination plant which is always ready for immediate installation whenever the call comes. It has been used in a number of instances during actual epidemics, and in every case the epidemic has been immediately checked.

The speaker would be disappointed, indeed, if he left an unqualified impression that the general improvement in the sanitary quality of water supplies of the state, and the resultant marked reduction in typhoid fever mortality in the state were due *solely* to the efforts of the Engineering Division of the State Department of Health. That its efforts have constituted a primary force in the accomplishment of these ends will be clear to any one who cares to study the local history and chronology of these improvements in connection with our investigations and reports. Alone, the work of the Engineering Division would have accomplished little; in fact, would have been largely ineffectual, without the coöperation of other agencies such as the sanitary supervisors, local health officers, and particularly the superintendents and officials of local water boards and water companies, whose assistance in the field has been both necessary and invaluable.

PROCEEDINGS.

November Meeting.

Hotel Brunswick,
Boston, November 12, 1919.

Mr. Samuel E. Killam, President, presiding.
The following members and guests were present:

Honorary Members.

E. C. Brooks. F. E. Hall. R. J. Thomas. — 3.

Members.

L. M. Bancroft.	F. J. Gifford.	Morrison Merrill.
C. R. Barker.	T. W. Good.	Leonard Metcalf.
A. E. Blackmer.	H. J. Goodale.	H. A. Miller.
J. W. Blackmer.	F. W. Green.	M. L. Miller.
Bertram Brewer.	F. M. Griswold.	William Naylor.
Eugene Carpenter.	I. H. Henderson.	F. L. Northrop.
J. S. Caldwell.	D. A. Heffernan.	H. E. Perry.
R. D. Chase.	G. A. Johnson.	H. F. Salmonde.
W. R. Conard.	J. M. Jones.	P. R. Sanders.
J. E. Conley.	Willard Kent.	C. W. Sherman.
F. L. Cole.	S. E. Killam.	Sidney Smith.
F. A. Darling.	A. C. King.	G. H. Snell.
J. H. Dillon.	G. A. King.	R. H. Stearns.
A. O. Doane.	F. H. Luce.	H. A. Symonds.
A. W. Dudley.	D. B. McCarthy.	D. N. Tower.
E. D. Eldredge.	F. A. McInnes.	W. A. Tripp.
F. L. Fuller.	Hugh McLean.	R. S. Weston.
C. B. Garmon.	H. V. Macksey.	F. I. Winslow.
Patrick Gear.	J. H. Mendell.	M. B. Wright. — 57.

ASSOCIATES.

Bond, H. L. Co., by F. M. Bates.
Builders Iron Foundry, by A. B. Coulters.
Byers, A. M. Co., by H. F. Fiske.
Central Foundry Co., by R. W. Conrow.
Fire & Water Engineering, by R. H. Lockwood.
Goulds Mfg. Co., by C. W. Fulton and H. F. Miller.
Hayes Pump & Machinery Co., by F. H. Hayes.
Hersey Mfg. Co., by J. H. Smith.
Leadite Company, The, by George McKay, Jr.
Lead Lined Iron Pipe Co., by T. E. Dwyer.
Ludlow Valve Mfg. Co., The, by A. R. Taylor.
National Meter Co., by J. G. Lufkin and M. L. Miller.
National Tube Co., by H. T. Miller.
National Water Main Cleaning Co., by B. B. Hodgman.
Neptune Meter Co., by D. B. McCarthy and W. H. McGarry.
Pittsburgh Meter Co., by G. C. Northrop.
Power Equipment Co., by E. F. Leger.
Rensselaer Valve Co., by C. L. Brown and I. A. Rowe.
Smith, A. P. Mfg. Co., by F. L. Northrop.
Thomson Meter Co., by E. M. Shedd.
N. Y. Continental Jewell Filtration Co., by A. M. Crane.
Union Water Meter Co., by D. K. Otis and H. W. Jacobs.
Warren Foundry & Machine Co., by H. H. Kinsey.
Wood, R. D. & Co., by R. M. Simon.
Worthington Pump & Machinery Corp., by Samuel Harrison.
Gamon Meter Co., by R. J. Thomas. — 31.

GUESTS.

MASSACHUSETTS.

Boston, Dr. P. E. Gear, J. B. McNamee, and Prof. W. H. Walker.
Winchester, H. W. Dotten.

NEW YORK.

Charles A. Whitney. — 5.

The Secretary presented applications for membership from C. P. Hsueh, New York City, draftsman New York Central Railroad Co.; G. G. Hare, city engineer, St. John, N. B.; George A. Adams, Dedham, Mass., superintendent Needham Water Department; George E. Ahern, Arlington, Mass., superintendent public works; Osgood N. Mayhew, Oak Bluffs, Mass., superintendent Cottage City Water Company; Albert C. Roberts, Lakeville, Conn., manager and treasurer, Lakeville Water Company; George E. Russell, Arlington Heights, Mass., assistant professor of hydraulic engineering, Massachusetts Institute of Technology;

John F. Lucey, Somersworth, N. H.; Harold S. Palmer, Trinity College, Hartford, Conn., Ground Water Division, U. S. Geological Survey in Connecticut and Idaho; Charles A. Holden, Hanover, N. H., director of the Thayer School, professor of civil engineering, Dartmouth College, — ten applications all properly endorsed and recommended by the Executive Committee. All were duly elected.

The Chicago Meeting of the Engineering Council.

The Secretary read a communication* from Langdon Pearse, delegate to the meeting of the Engineering Council, held in Chicago, April 23–25, 1919.

Department of Public Works.

The Secretary read the following report of the committee to which was referred Senate Bill 2232, entitled "A Bill to Create a Department of Public Works," etc.:

Woburn, Mass., November 3, 1919.

The Committee to which was referred Senate Bill 2232, entitled "A Bill to Create a Department of Public Works and to Define its Duties," having considered same, begs leave to submit the following report:

Whereas: The New England Water Works Association has through its Executive Committee, and also through a special committee appointed for that purpose, considered Senate Bill No. 2232, presented at the first session of the sixty-sixth Congress, entitled "A Bill to Create a Department of Public Works, and to Define its Powers and Duties." Therefore be it

Resolved: That the New England Water Works Association firmly believes that such a department is necessary, and that the said bill is in general principles a wise measure, and that it recommends that its members individually give all the assistance that they can towards the final passage of the bill.

Be It Further Resolved: That a copy of this vote be forwarded to the Engineers, Architects, and Constructors Conference on National Public Works.

For the Committee,

H. V. Macksey,
Chairman.

The report was accepted and resolutions adopted.

* On file at office of New England Water Works Association.

The Secretary also read a communication from James Jackson, division manager of the Red Cross, calling attention to the Red Cross campaign for membership.

Prof. William H. Walker, of the Massachusetts Institute of Technology, presented a paper on "The Prevention and Cure of the Red Water Plague."

The discussion was participated in by Mr. Frank W. Green, Col. George A. Johnson, and Mr. Robert Spurr Weston.

Mr. Creed W. Fulton, New England manager of The Goulds Manufacturing Company, Boston, read a paper, illustrated by stereopticon views, on "Modern Pumps for Small Water Works."

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., November 12, 1919, at 11 A.M.

Present, President Samuel E. Killam and members Henry V. Macksey, Charles W. Sherman, Percy R. Sanders, James H. Mendell, Frank J. Gifford, Patrick Gear, Henry A. Symonds, Lewis M. Bancroft, and Willard Kent.

Ten applications for active membership were received, viz., George A. Adams, superintendent water works, Needham, Mass.; George E. Ahern, superintendent public works, Arlington, Mass.; G. G. Hare, city engineer, St. John, N. B.; Charles A. Holden, director of Thayer School of Civil Engineering, Hanover, N. H.; C. P. Hsueh, New York, N. Y.; John F. Lucey, superintendent water works, Somersworth, N. H.; Osgood N. Mayhew, superintendent Cottage City Water Company, Oak Bluffs, Mass.; Harold S. Palmer, professor of geology, Trinity College, Hartford, Conn.; Albert C. Roberts, manager and treasurer of the Lakeville Water Company, Lakeville, Conn.; George E. Russell, associate professor of hydraulic engineering, Mass. Institute of Technology, Cambridge, Mass.; and they were by unanimous vote recommended therefor.

The report of the committee on memoir of John Mayo, of Bridgewater, Mass., was received and ordered printed in the JOURNAL of the Association.

The death of Irving S. Wood, of Providence, R. I., a member of the Association since March 8, 1905, who died the 20th ult., was announced and the President was authorized to appoint a committee on memoir.

A communication from the Red Cross Association was presented and ordered read at the meeting of the Association.

The report of Mr. Langdon Pearse, representative of the New England Water Works Association to the Chicago meeting of the

Engineering Council, was presented, together with the report of the Committee on "Senate Bill No. 2232, To Create a Department of Public Works and Define Its Powers and Duties," and they were ordered submitted to the meeting of the Association.

On motion of Mr. Macksey, it was voted: That, as a general rule, subject to the discretion of the Editor, galley proofs shall not be submitted to the authors for correction.

After discussion of the subject of the substitution of bond for certified check with proposals for furnishing water-works material, the President was authorized to appoint a committee on the subject, to report at the annual meeting of the Association.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

REPORT OF COMMITTEE ON BUDGET FOR 1920.

[*Read at December 10, 1919, meeting.*]

To the Members of the New England Water Works Association:

Gentlemen, — The committee appointed " to make a study of the finances of the Association and report on a budget system for 1920 " submits the following report:

The income of the Association may be classified under four heads: first, moneys received from membership dues and fees; second, moneys from advertisers in the Journal and subscriptions to and sales of the same; third, dividends and interest on invested funds; and fourth, miscellaneous receipts made up largely from the sale of dinner tickets.

From the present membership (July, 1919) of 797 members and 72 associates, we may expect to receive a total income of $4 628. The income from the Journal has averaged, for the last nine years, $2 265 per year, and your committee places the approximate income from this source at $2 250.

Dividends and interest have averaged $203 annually, and we have estimated this income as $200.

The income from miscellaneous sources has averaged about $968 per year, and we have called it $950, thus making the total annual receipts $8 028.

It has seemed unwise to estimate moneys received from initiation fees, as these are so variable, and they have been omitted as a source of positive income. In 1916 we received from fees $682, but in 1918 the amount was only $97.

In December, 1917, the dues of members were raised from $3 to $4, and of associate members from $15 to $20. Had the membership of the Association remained the same as it then was, namely, 901 members and 87 associates, the income would have been $716 more per year than on the basis of the membership of

July 1, 1919, which are the membership figures your committee has been obliged to use in estimating the present income of the Association.

That this loss in membership cannot be due wholly to the raising of the dues is shown by the fact that the Association lost 41 members the year previous to that in which the dues were raised as against 86 lost the year they were raised. The year previous to the raising of the dues the Association gained 3 associate members, while the next year saw a loss of 10 associates and last year it lost 5 more.

The present approximate expenditures of the Association may be classified as follows:

Office expenses:

Salary of Secretary	$200.00
Salary of Assistant to Secretary	1 080.00
Rent	550.00
Membership lists	300.00
Expenses of Secretary	50.00
Expenses of Assistant to Secretary	150.00
Printing, stationery, and postage (average for seven years, $301)	300.00
	$2 630.00

The "office expenses" of the nine years 1910–1918 have averaged $2 074 per year.

Expenses of meetings and committees:

Stereopticon (average, $55)	$75.00
Dinners and incidentals connected therewith	900.00
Printing, stationery, and postage	300.00
Treasurer's salary and bond	70.00
Incidental expenses	200.00
	$1 545.00

Average for nine years, $1 800.

After a careful study of the receipts and expenditures of the Association, the committee recommends the following:

BUDGET FOR 1920.

Salary of Secretary	$200.00
Salary of Assistant to Secretary	1 080.00
Rent	550.00
Printing of membership lists	300.00
Expenses of Secretary and Assistant to Secretary	130.00
Printing, stationery, and postage	400.00
Dinners and incidentals connected therewith	900.00
Treasurer's salary and bond	70.00
Incidental expenses	270.00
	$3 900.00
For publication of the JOURNAL	4 100.00
Total	$8 000.00
Estimated receipts	$8 028.00

The reduction in expenses of Secretary and Assistant to Secretary have been made by the committee not as a criticism of present methods but in the belief that if it is necessary to practice strict economy in all departments of the Association it will be feasible for these expenses to be reduced as well.

The committee feels that a material reduction can be made in the cost of printing and stationery by discontinuing the practice of furnishing special letterheads for each officer and each member of a committee of the Association. It recommends that one standard form of letterhead be printed, containing the name of the Association but excluding the list of officers and committees, and, similarly, for stamped envelopes, in order that the one form may be suitable for any one connected with the Association, and for one year as well as another. It also recommends that as far as possible the printing of letterheads and stamped envelopes be done by one printing concern in sufficient amount to furnish letterheads and envelopes for at least six months' supply, and, if conditions warrant, for one year's supply. The committee believes that still further economy can be had by changing the form of meeting

announcements to a sheet printed on one side only and by eliminating all matter which may not be strictly necessary.

The committee does not wish to criticize the practice of having special letterheads or the present form of meeting announcements. All of these features are attractive, if the finances of the Association warrant the expense. In this case, however, it seems apparent that with present high prices, the strictest economy must be practiced if the expenses are to be kept within the present income.

As the increasing cost of printing the JOURNAL is one of the most serious items of expense which the Association is called upon to meet at the present time, the committee recommends that all but the most essential portions of the proceedings valuable for future reference be eliminated. The material printed might include the annual reports of the Secretary, Treasurer, and Editor, the names of new members elected to the Association, and possibly certain important motions passed by the Association.

The committee further recommends the Secretary be directed to keep a loose-leaf, typewritten record book constituting the official record of the proceedings of the Association, which shall be written out in full and shall contain all data as at present recorded. This record book should be kept on file at Association rooms, where it can be consulted by the proper persons.

As it often happens that in papers read before the Association there may be some matters of transient interest only, the committee recommends, as an additional means of bringing the expenses of printing within the appropriation allowed for the JOURNAL, that the Board of Editors be requested to consider the feasibility of omitting from publication such portions of papers presented as said board may deem expedient and wise.

Your committee would call attention to the fact that there will be no value in the establishment of a budget system unless it is made the business of some one to see that the expenditures are kept within the several amounts appropriated. In order that this may be accomplished, the committee recommends that the Executive Committee be directed not to exceed the several expenditures authorized in the budget without a vote of the Association.

For the purpose of keeping the Executive Committee in close

touch with the financial condition of the Association, the committee recommends that the Secretary and the Treasurer be required to furnish to the Executive Committee a monthly statement of receipts and expenditures, classified in such a way that the said committee may be able to check up these expenditures against the budget.

The loss of 145 members and 12 associates since the maximum membership of 1 043 on January 1, 1917, indicates the necessity of making a drive for new members. In the three years of 1914, '15, and '16, the Association gained 256 members and 24 associates, and now that the war is over and affairs are more nearly normal it would seem entirely feasible to win back many of those members, who have resigned for one cause or another, and to add new members, thus bringing the membership of the Association back to and possibly above its maximum figure of 1 043.

In closing this report the committee would summarize its recommendations as follows:

The adoption of the budget presented:

That the Executive Committee be directed not to exceed the several expenditures authorized in the budget without a vote of the Association.

That the Secretary and Treasurer be directed to furnish the Executive Committee with a monthly statement of the receipts and expenditures, classified according to the items of the budget.

The adoption of a standard form of letterhead and envelope suitable for all official uses and unlimited as to time in which such stationery must be used.

That, so far as possible, the printing of all stationery be done by one concern and in quantity sufficient for at least one year's supply.

That, for the present, the announcements of meetings be made on a sheet printed on one side only, and that all matter not strictly necessary be eliminated from such announcements.

That in printing the JOURNAL all but the most essential portions of the proceedings be eliminated.

That the Secretary be directed to keep a loose-leaf, typewritten record book constituting the official record of the proceedings of

the Association, which shall be written out in full, and that this record book shall be kept on file at the Association rooms.

That the Board of Editors consider the feasibility of omitting from publication in the JOURNAL such portions of the papers presented before the Association as it may deem expedient and wise.

That the Association consider the advisability of a drive for new members.

Respectfully submitted,

GEO. A. CARPENTER.
EDWIN L. PRIDE.
FRANK A. MARSTON.

BOSTON, December 10, 1919.

JOHN MAYO.

John Mayo was born in Weston, Herefordshire, England, in 1859, and died at Bridgewater, Mass., August 21, 1919.

He settled in Bridgewater in 1880, and there married Martha Husbands, who with his two daughters, Annie M. Dorr and Sarah W. Mayo, survive him.

His first employment in Bridgewater was as a clerk in a market and he later engaged in a similar business on his own account.

In 1900 he was appointed superintendent of the Bridgewater Water Company, and in 1902 he was elected tax collector of the town of Bridgewater, both of which offices he retained until his death. His efficient conduct of both offices was highly satisfactory to his townspeople, and his books and records were models of neatness and accuracy.

For many years he was a regular attendant of the First Congregational Church (Unitarian) in Bridgewater, and was active in all matters pertaining to its welfare.

For twenty years he was secretary of Fellowship Lodge, A. F. & A. M., in his home town. He was for many years, also, treasurer of the board of trustees of Mt. Prospect Cemetery in Bridgewater. For thirty-six years Mr. Mayo was a member of the Bridgewater Fire Department, during many years of which period he was one of the fire engineers. He was especially interested in the electric fire-alarm system, and through his efforts the same was maintained with a high degree of efficiency.

He was a director of the Bridgewater Coöperative Bank and an incorporator of the Bridgewater Savings Bank.

He was elected a member of the New England Water Works Association in February, 1904.

In all his varied activities he displayed that same care and thoroughness and high sense of duty which characterized his whole

life. Quiet and unassuming in his manner, he was nevertheless a tireless worker in all matters for the benefit of his town.

His family life was unusually congenial, and in his church and fraternal affiliations his wise counsel and steadfast support were highly valued and will be greatly missed.

ARTHUR E. BLACKMER, *Chairman*,
D. N. TOWER,
A. C. HOWES,
HORACE KINGMAN,
Committee.